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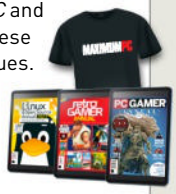

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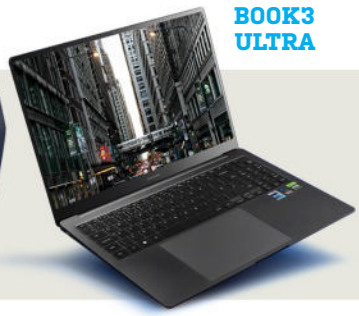

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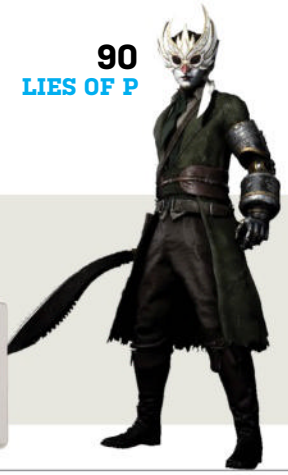

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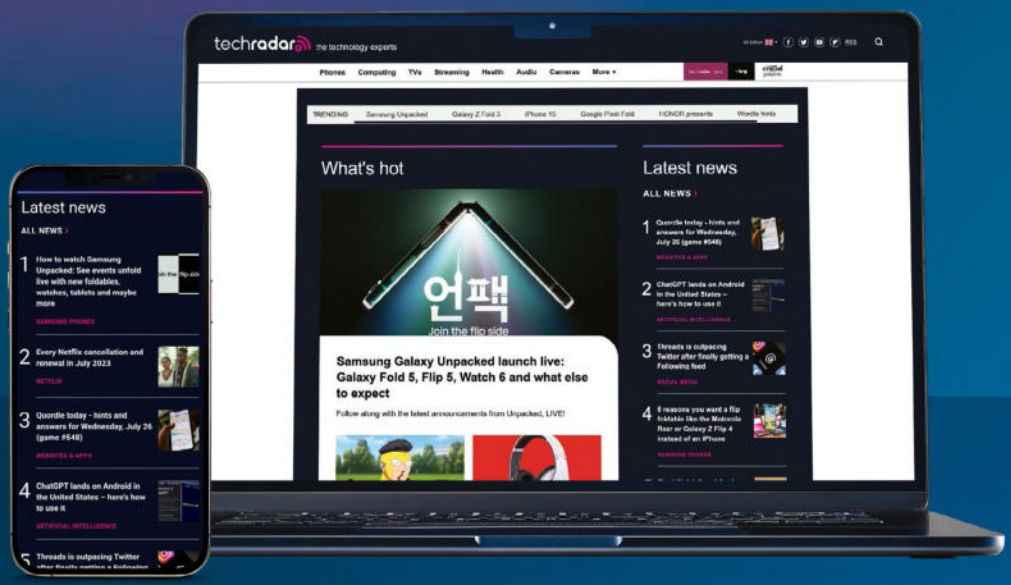

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Guy Cocker

GAMER'S DELIGHT

WE'VE BEEN A BIT down on 2023's graphics cards, thanks to a pretty toxic combination of inflated prices, lackluster performance, and a lack of a generational improvement over previous GPUs. Thankfully, we've finally been able to dish out a positive review due to the arrival of AMD's RX 7800 XT (see page 76). At $500, it isn't "cheap", but it is a card that a lot of you reading this will actually be able to afford. It also punches above its weight in performance, taking the fight to Nvidia's $600 RTX 4070 and beating the $100 more expensive card in many titles. True, AMD's a generation behind Nvidia in terms of ray tracing and AI-powered features, but this is the sort of competition we've been hoping for since this latest generation of overpriced cards were released. True, Nvidia's unlikely to drop the price of its RTX cards, but hopefully the Green Giant will be rattled by AMD's mid-range challenger. After all, we're the ones that benefit from healthy competition.

We were so impressed with the RX 7800 XT, in fact, that we also made it the star of this month's cover build. Those of you following our Story of the Build videos (page 16) from previous issues will know that Sam's been keen to do something around AMD's top-end RX 7900 XTX card, but we decided to put that on hold in favor of what we think will be a far more popular card. For an extra boost of gaming performance, we couldn't resist pairing AMD's new card with one of its 3D V-Cache CPUs, namely the 7800X3D. What's impressive is that the whole machine comes in at just over $2,000, which is pretty good for a Zen 4/RDNA 3 PC. But is it the best choice if you're looking for a 1440p gaming machine in late 2023? Sam's benchmarked it to find out.

I'd received letters over the last few months asking for more features from our expert writers, Jarred Walton and Jeremy Laird, and this month we have two of their famously in-depth pieces for you to chew on. The first is a guide on how to upgrade your Steam Deck's SSD from Jarred (page 32), so you can take advantage of both more capacity to store your favorite games, as well as improved load times. We've been reviewing more and more handheld PC gaming devices recently, including one the OneXFly on page 80, but as we note, the Steam Deck's low price makes it the most popular. Then, Jeremy gets out his crystal ball on page 42 to see if Arm's chips will ever replace the x86 ones in your PC, or if in the age of AI, that question is redundant. It's a classic *Maximum PC* deep dive into the future of the platform, so I hope you enjoy it.

Photoshop's Generative AI also makes it out of beta this month and into the main version. To celebrate, we show you how to use this compelling new feature. Whether it's adding backgrounds, or taking away something you wish wasn't there, it's easier than ever to edit your photos without needing specialist skills. Find out how on page 70. I've also heard feedback that we do too much on Chrome rather than other browsers, so this issue we look at how Opera's tab islands make browsing more organized than ever. I personally loved trying this new feature and improving my browsing experience, so if you got a bit too used to Google's browser, I urge you to take a look.

Enjoy the issue!

Guy Cocker

Guy is Maximum PC's *editor-in-chief. He built his first gaming PC in 1997 to play* Tomb Raider *on 3dfx, and has been obsessed with all things PC ever since.*

↘ submit your questions to: editor@maximumpc.com

THE NEWS

Intel's Raptor refresh

New world's fastest desktop processor. Possibly...

BY THE TIME you read this, Intel will have released the first of its new 14th generation Raptor Lake refresh processors. This initial batch will consist of three versions, with two variations of each. We have, in order of power, the Core i9-14900K, i7-14700, and i5-14600, each in "K", and "KF" configurations (all unlocked, but the Fs lack integrated graphics). As usual, Intel has opted to release the best first. That best has eight performance cores and 16 efficiency cores, plus a base P clock of 3.2GHz. Memory support runs to DDR5-5600—not the rumored 6400 that some had hoped for.

The rest of the range is expected in the new year, and will expand the range to 26 versions in all, including two that don't even warrant i3 status, as they only contain two performance cores. These appear to be taking the role of Intel's Pentium Gold and Celeron brands. The core counts are the same as the previous generation of Raptor Lake, except for the i7's, which get an extra four efficiency cores, taking them to a 8+12 configuration. There are speed tweaks across the board, in the order of 100MHz for the most part. DDR5 memory speeds drop to 4800 at the i5 and below. All models retain DDR4-3200 support, so new memory isn't required.

As we get close to release, engineering samples will do the rounds, and inevitably unofficial benchmarks leak, too. It's early days, but one fairly reliable source has put the top chip, the Core i9-14900KF, through Geekbench 6 and achieved 3,347 on the single-core test. This is 13 percent faster than the i9-13900K, and 15 percent faster than the Ryzen 9 7950X. It also scored 23,051 on the multi-threaded test—15 percent better than the 13900, and 20 percent over the Ryzen. The test reportedly used DDR5-7000 memory, so some tweaking was going on, but it is an encouraging start.

Much of the credit goes to its high boost clock of 6GHz. It remains to be seen if we will get a faster KS version, although we suspect if Intel could have made it faster, it would. Still, if this test is accurate, it makes the i9-14900K the fastest desktop processor to date. This accolade is contested, and no doubt this chip was binned to make sure Intel can keep making that claim. We'll see when we put the chip through its paces soon. Gaming performance is a separate issue. Here, AMD and Intel will be near neck and neck.

Lower down the range, there will be a small uplift, but nothing dramatic. One leaked internal forecast puts performance at an average of a three percent increase over the equivalent 13th generation chip. The new Core i7's fare a little better in multi-threaded tests thanks to those extra E cores, which take the total core count to 20 and give about a 17 percent improvement. For the most part, expectations are muted. As a generational uplift, it could be a marketing problem. The refresh could also be turned into good news by simply cutting prices, but rumors have it that Intel will remain pretty bullish.

This Raptor Lake refresh is born of expediency, not design. It may sport a 14th generation moniker—the naming convention forced Intel's hand—but these are essentially the same processors, only warmer. The next big launch was supposedly going to be Meteor Lake, but it's unclear if that was ever destined for the desktop, and now looks set to be restricted to mobile PCs. A recent report from Japan claims Intel will be making about 365,000 Meteor Lake chips a month. This is a reasonable number for the mobile market, but not enough to cover desktops too, bar possibly a few specialist systems. Arrow Lake, due next year, will be the shift of pace we've been waiting for, and will introduce new core architectures for both performance and efficiency cores, with up to 32 efficiency cores rumored, plus an integrated AI core, and a new process to boot.

If you're still running an Alder Lake motherboard, therefore sporting an LGA1700 socket, then these refreshed chips are an attractive upgrade. If you've already jumped onto a Raptor Lake system, then there is little here to interest you, unless you really must have the very best you can get. Otherwise, the Raptor Lake refresh is going to be a bit disappointing. Still, Intel will remain competitive despite this hiccup and, as ever, distract us all with a lovely halo chip clocked up into the stratosphere. **–CL**

"Intel's gearing up for the launch of its 14th gen CPUs

© INTEL

AFFORDABLE MACBOOK?

STUDENTS AS WELL AS educational establishments love Chromebooks. It's a big market, which more than doubled after the pandemic. In 2020, over 30 million were sold. Apple is rumored to be planning an affordable MacBook to cut itself a slice of those sales. The whisper comes from "industry sources", who claim Apple is working on a Chromebook-style laptop for as early as the end of next year. Quite what Apple thinks of as affordable remains to be seen, but a typical Chromebook is $250-300, and can go as low as $100 (although we wouldn't recommend you do). Apple is on the other end of the scale; MacBook ranges start at $999, and rises rapidly to $6,499. Apple's CEO, Tim Cook, has previously described Chromebooks as "test machines", but numbers tend to count. It won't hurt to give the next generation a taste of Apple kit early, and hope they stick around for the expensive stuff. **–CL**

GOODBYE THIRD-PARTY PRINTER DRIVERS

THIRD-PARTY printer drivers haven't always been the most compliant software, updates often causing problems. It seems Microsoft has had enough of a multitude of drivers; Windows is to take control by 2027. 2025 will see no new printer drivers on Windows Update; 2026 will actively push Windows IPP inbox drivers, and in 2027, third-party drivers will vanish from Windows Update (bar important security-based updates). Existing third-party drivers for old printers will still be available, but all-new printer drivers will be under the auspices of Windows. We can only hope that Microsoft's drivers won't pull tricks such as refusing to run the scanner function on your all-in-one when it runs out of ink, refusing to print in black because your color cartridge is low, or present warnings about low ink when you have plenty left. Poorly written drivers were the bane of earlier iterations, so finally one of the worst culprits is being brought to heel. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

ARTIFICIALLY RECOVERED TAXES
The IRS is to use AI to check taxpayers' returns for compliance.

ATARI REBORN
The new Atari 2600+ console will play the original cartridges, this time via HDMI.

CERAMIC STORAGE
A start-up is making claims about its nanolayer ceramic storage, including a 5,000-year life and 100 petabyte cartridges.

TRAGEDIES

RAPTOR'S BSOD
The recent rash of blue screens is down to microcode in MSI mobos causing 13th generation chips to be unrecognized.

SERVER CRASHES CAR FACTORIES
12 of Toyota's assembly plants lost two days' production due to insufficient server disk space.

38TB DATA LEAK
Microsoft's AI research division accidentally exposed private internal data onto GitHub.

AMD'S V-CACHE CPU GOES MOBILE

New Asus ROG is a monster

THE RED TEAM'S party trick of layering a slab of cache over the processing cores to make a blistering chip, especially for games, has finally found a home in a laptop. The chip is the Ryzen 9 7945HX3D, and has 16 Zen cores with 128MB of L2 cache. The base clock is 2.3GHz, with a top boost of 5.4GHz. It is, as AMD boasts, the best mobile gaming chip in the world.

We first got wind of this beauty when the specifications of the Asus ROG Strix Scar 17 G773 laptop broke cover. That laptop has arrived, and Asus claims it as the pinnacle of Windows gaming. The chip gets partnered with a 16GB Nvidia GeForce RTX 4090 or 4080 Laptop GPU, and a 17-inch 1440p screen with a maximum refresh rate of 240Hz. There's 16GB of DDR5-4800 memory, with the potential to fit up to 64GB. Storage is thanks to a 1TB or 2TB NVMe. There are a raft of gaming touches, including a per-key RGB mechanical keyboard, and noise cancelling. It's not a lightweight at a full 6.6lbs, but it is respectably thin at under an inch thick.

There are four versions, depending on GPU and storage capacity. An RTX 4090 version with a 1TB drive will set you back a cent shy of $3,500. That's not as much as some predicted, and given the cutting-edge hardware on board, it's not bad. Performance against a non-3D-Cache version depends on the game. Some can make good use of the extra room—*Shadow of the Tomb Raider* averages over 170fps at 1440p, while others show little gain. Battery life is pitiful, but given the power requirements of the hardware, that is expected. It's also a bit noisy. Still, it is the most powerful gaming laptop in the world. More please, AMD. **–CL**

This ROG gaming behemoth is the most powerful gaming laptop around, thanks to AMD's cache trickery.

© APPLE CORP, ROG

UNITY TO CHARGE FOR INSTALLATIONS

New plan derided by developers

UNITY HAS DECIDED THAT from 2024, it will charge 20 cents every time a game is installed; the Unity Runtime Installation Fee. However, there will be a threshold before it applies. For Unity Personal and Unity Plus, it kicks in when you have made over $200,000 in a year and have 200,000 installations. For Unity Pro and Enterprise, those figures are a million each.

To compensate, Unity will restructure subscriptions. However, game developers are not happy. Once you hit the threshold, you'll owe Unity $1 for every five installations, spelling trouble for low-cost or free games. Any that rely on in-game purchases could be very problematic.

It's also a blow for cheap mobile games, an area that Unity dominates. It's not clear how it will account for repeated, possibly malicious, re-installations. To make it worse, the thresholds are retroactive, so many existing games will have to pay fees from the new year.

The response prompted Unity to apologize for "confusion and angst". Committing to a long-term game development project requires trust—sudden radical changes in charges don't inspire this. The reason is easy to guess—Unity is losing money. Its stock has dropped 80 per cent since a peak in 2021, soon after it went public. Now, it has shareholders to placate.

Some developers have quit, while others will move future projects to other engines. The second biggest player is the Unreal Engine. This is free (Unity has a subscription for its pro version), but after you've made your first million, it charges five per cent royalty. For a free, open-source engine, there's Godot. This move from Unity is clumsy at best, desperate at worst, and might not end well. **–CL**

14th Gen mobos

A NEW GENERATION OF INTEL CHIPS is usually a boon for the motherboard companies. Switching chip generations usually means a new socket and chipset, necessitating a new motherboard. Not this time. It's a refresh, and Z790 boards will do, given a BIOS update at least.

This hasn't stopped the usual suspects from announcing a new raft of 14th generation motherboards to tempt you to upgrade. Like the processor, these are a refresh. What could tempt you? The best of the new boards offer Wi-Fi 7. It's meant to offer a 20 percent increase in data transfer over version 6.

Then we have PCIe 5.0 M.2 SSDs, which have just started to deliver a theoretical doubling of transfer speeds. Unlike the 13th Generation chips, you now get 20 PCIe 5.0 lanes, so you can spare four for your M.2 card and keep the graphics card on the full 16. The number of M.2 slots has proliferated, too.

You'll also get the latest memory standards up to DDR5-8266. AI has reached motherboards in the form of overclocking and thermal regulation, too. Other bells and whistles have been thrown at the new designs: lots of RGB, customization, heat dissipation, oodles of front and back ports, fancy audio, and anything else they could think of. The best of the new boards include Gigabtye's Z790 Aorus Pro X, which boasts a Sensor Display Panel to connect a small secondary display.

Asus has three ROG boards, including the top-tier Maximus Z790 Dark Hero, and the TUF Gaming Z790-Pro WiFi. It's a tough call if you've a perfectly good Z790 board already. These Raptor Lake chips will certainly be the last time you'll need one. If you plan on moving onto Arrow Lake within a year or two, it's a marginal call. **–CL**

Hidden-cable cards

Asus has developed a new way to deliver power to graphics cards. Instead of plugging power cables into the card, they go into the motherboard. The power gets to your card via an extra edge connector behind the PCIe slot, known as the HPCE connector (High Power Card Edge Connector). There's no need for awkward bending of cables, no matter what size card or case. The system is capable of providing up to 600W, which should be enough for now. If not, the specifications indicate that it can be raised to 900W. This new standard requires compatible motherboards and graphics cards, of course. Asus has just released the first one of each. The company is now partnering up to try and get the new standard adopted. It is a neat solution, especially given the initial troubles the 12VHPWR connector produced. **–CL**

20Gb/s from Thunderbolt 5

Intel has revealed the specifications for Thunderbolt 5, which offer an increase over version 4's 40Gb/s. Version 5 can reach 80Gb/s on bi-directional transfers, and 120Gb/s using a new boost mode for video. This is the first speed increase since the Thunderbolt 3 in 2013. It's enough bandwidth to run two 8K monitors or a single panel at up to 540Hz. The first controllers are due next year, with compatible devices to follow the year after. Thunderbolt was developed with Apple in 2011, and combines PCIe Express and Display port into one. Unlike a USB-C port, a Thunderbolt port has a single set of required capabilities, and can also double as a standard USB-C port, as this standard is a subset of Thunderbolt. Apple has always been keen on it.**–CL**

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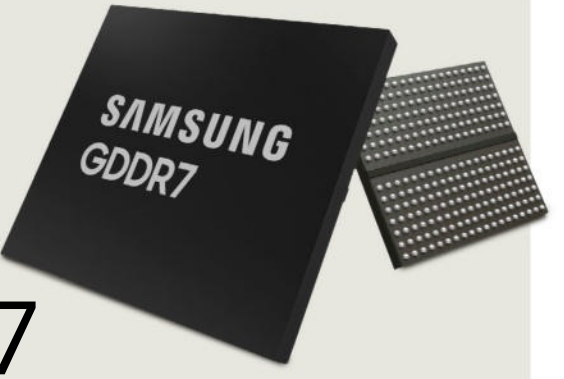
Jarred Walton

TECH TALK



Samsung GDDR7 Heads for 32Gbps

DRAM IS AT THE HEART of many computing devices. Whether it's DDR4 and DDR5 in PCs, HBM2 and HBM3 in GPUs, or GDDR6 and GDDR6X in graphics cards, a lot of the building blocks remain the same. It's the signaling that get upgraded, and now GDDR7 is on its way, with Samsung modules in production and Micron's alternatives to arrive in 2024.

It's a safe bet that GDDR7 will end up in the next-generation AMD, Nvidia, and Intel GPUs. We don't expect any of those to start shipping until 2024 at earliest—Intel's Battlemage architecture will almost certainly be the first "next-gen" GPU to arrive—so we still have plenty of time. But the transition is otherwise right on schedule.

The first GDDR6 graphics cards launched in 2018 with Nvidia's RTX 20-series, with GDDR6 at 12–15.5 Gbps (GTX 1650 to RTX 2080 Super). AMD RDNA GPUs also used GDDR6, again ranging from 12–14 Gbps. Two generations later, the latest Nvidia Ada and AMD RDNA 3 GPUs have pushed GDDR6 speeds of 17–20 Gbps, with GDDR6X clocked as high as 22.4 Gbps for the Nvidia RTX 4080.

That represents a 43 percent increase in bandwidth per GDDR6 module over the past five years, but even the highest-rated 24 Gbps GDDR6 pales in comparison to GDDR7. Samsung indicated targets of 36 Gbps in late 2022, but production modules have base speeds of 32 Gbps—33 percent higher than the fastest GDDR6, and 60 percent higher than the 20 Gbps chips used by AMD. It's a good thing, as even with large L2 and L3 caches, the latest GPUs are starting to run out of bandwidth.

With GDDR7, a future 384-bit memory interface would boast up to 1.536 TB/s of bandwidth. The RTX 4090, meanwhile, tops out at 1.008 TB/s, and the RX 7900 XTX offers 960 GB/s. Similar gains would be available on narrower interfaces as well, though costs might keep budget and mainstream devices on GDDR6 for another generation.

> GDDR7 can reach higher clock speeds in part thanks to its PAM3 signaling

GDDR7 can reach higher clock speeds in part thanks to its PAM3 signaling—Pulse Amplitude Modulation signaling with three distinct signaling levels. GDDR6 uses PAM2, but GDDR6X already uses PAM4 with four signaling levels. PAM3 will increase the memory controller's power consumption, as well as heat generated on the memory modules, for the encoding and decoding of the signals. PAM4 was certainly a part of why the earlier GDDR6X chips ran so hot, but current GDDR6X seems to have things under control, and GDDR7 should be more than manageable.

The initial Samsung GDDR7 modules come with a 16Gb capacity, like the GDDR6 and GDDR6X chips. That will likely be the lower limit for GDDR7, but the question is where the higher-capacity chips will go. 32Gb capacities seem likely, packing 4GB per chip. That would enable up to 16GB of memory on a 128-bit interface, or 48GB on 384-bit. Double the chips per channel, like Nvidia and AMD on professional GPUs, and 96GB GPUs are possible.

Samsung already has GDDR7 memory modules in production, which seems like an easy pick for future GPUs and other devices.

But 32Gb modules might not be the only higher-capacity options. In the past year, we've started seeing non-power-of-two DDR5 memory modules. That's thanks to 24Gb DDR5 modules, which enables up to 48GB DIMMs and 192GB total for four DIMM slot motherboards. Samsung hasn't confirmed that it will offer 24Gb GDDR7, but it might make for an in-between capacity.

We're not sure where mainstream consumer hardware with a 128-bit interface needs to go to 16GB total VRAM, but 8GB isn't always enough, and having the option for 12GB while sticking with a 128-bit bus could be useful. 256-bit interfaces, meanwhile, could offer 24GB, rather 32GB, while 192-bit and 384-bit configurations could offer 18GB and 36GB. Will we see those in future graphics cards? My crystal ball still looks hazy, but I wouldn't count them out.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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THE LIST

THE BEST GAMING MONITORS

PICTURE THE SCENE: you've bought the best CPU and GPU you can afford, and you're kitted up with a game-winning keyboard and mouse. But you still need to make sure you save some cents for a great gaming monitor to deliver those cinematic thrills in single-player titles and fast response times to win multiplayer battles. These are the displays that deserve to be on your shortlist, whether you're on a budget or flush with cash.

3 GIGABYTE M32UC

We're finally in an era of gaming where an affordable 4K monitor and a fast 4K monitor are one and the same. Gigabyte has figured out a heady blend of features for that sort of money too, with two HDMI 2.1 ports, 1ms MPRT, FreeSync Premium Pro, and even a USB 3.2 hub.

You'll need a powerful graphic card to run at 4K, but if you have a top-end GPU, you can run at 144Hz out the box or overclock to 160Hz via DisplayPort 1.4. **www.gigabyte.com, $600**

5 PIXIO PXC277 ADVANCED

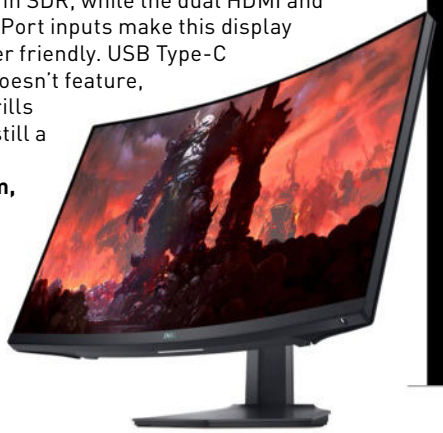
Pixio's monitor ticks all the boxes. It's a 1440p 165Hz 27-inch display, which is the sweet spot in terms of what most people would want across size, pixel density, and refresh rate. The 1ms response time is also pretty good, as is the VA panel. However, the backlight is monolithic, the HDR isn't worth activating, and the rated brightness is 320 nits, which is modest by today's standards. **pixiogaming.com, $240**

2 LG ULTRAGEAR 27GN950-B

The first 4K, Nano IPS, 1ms response time, Nvidia G-Sync/AMD FreeSync adaptive refresh rate gaming monitor is perfect for showing off what your GPU can do. It's also a looker, with a slick, slim-bezel design, offering LG's Sphere Lighting 2.0 RGB visual theatrics. The 144Hz refresh rate is enough for most gamers, although the lack of HDMI 2.1 and USB Type-C are a little limiting. **www.lg.com, $630**

4 DELL S2722DGM

Like our number 5 entry, this is another 1440p 165Hz 27-inch VA display, except it's from a more trusted brand. It's not as good value on a spec level though, only offering a slower 2ms GtG response, and no HDR support at all. Not to worry though, as games look great running in SDR, while the dual HDMI and single DisplayPort inputs make this display console-gamer friendly. USB Type-C connectivity doesn't feature, but it's a no-frills monitor, and still a good buy. **www.dell.com, $250**



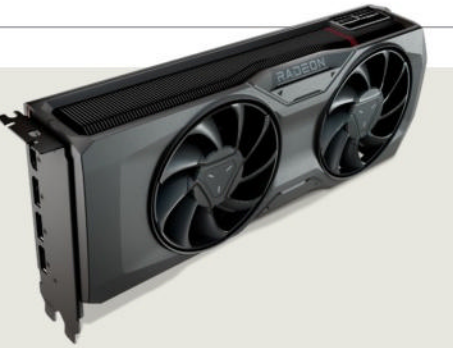
1 ALIENWARE 34 QD-OLED AW3423DWF

It's our favorite gaming monitor, and recent discounts have only made it more appealing. It's a 1440p ultrawide screen with a 165Hz refresh rate, but the headline spec is that this is an OLED panel, with inky blacks that make games like *Cyberpunk 2077* sing. It's not the best monitor for everyday use thanks to some fuzzy text reproduction, but for gaming, this is the crème de la crème. **www.dell.com, $900**

© PIXIOGAMING, DELL, GIGABYTE, LG.

Jeremy Laird

TRADE CHAT



Why does GPU pricing have to be so infuriating?

I NOTED A WHILE BACK that prices of pretty much everything had normalized with the pandemic receding and other supply chain abnormalities subsiding. The one exception were GPUs. Several months later, while graphics cards are cheaper, they still haven't returned to historical trends. But what's even more frustrating is that pricing just doesn't make sense.

The most recent example of this involves AMD's hot new Radeon RX 7700 XT and 7800 XT boards, but we'll come back to those GPUs in a moment. The overarching problem here, aside from the more obvious issue of painfully high pricing, involves comparative value for money.

Call it bang for buck or frames per dollar, whatever you prefer, the value curve when it comes to all manner of electronics has always been the same. You get more for your money at the lower end of the market.

For a product like a GPU, that means the absolute best-of-the-best graphics card might be five times the cost of an entry-level board, but only offer two or three times the performance. Somehow, however, that value scaling up as you move down through the range has been lost of late.

It all started with Nvidia's RTX 40 Series graphics cards. If you start out at the top of the RTX 40 range, you'll find that the RTX 4090 only increased in price a little over the old RTX 3090 from $1,499 to $1,599, but offered a major performance boost. However, as you move down through the range to RTX 4080 through the 4070 and 4060 models, you will find that the price jumps are much bigger over the old 30 Series, but the performance increases shrink.

Long story short, the RTX 4090 is the best-value GPU in the RTX 40 Series when you're doing a generation-to-generation comparison. Okay, the $299 RTX 4060 does usually deliver more frames per dollar than a $1,599 4090, provided the former isn't running out of VRAM. But when you compare, say, the 4060 Ti to the 4070 Ti, you don't get any more bang for your buck with the cheaper GPU.

> AMD's new 7800 XT is over 20 percent faster than the 7700 XT, but just 10 percent pricier.

The 4070 Ti is faster, but the price gap is pretty much proportional to the performance gap. That has never been the case with PC components in the past. Bang for buck always dwindled as you moved up the range, be that GPUs, CPUs, memory, or storage.

So we come back to those new AMD graphics cards. By AMD's own admission, the 7800 XT is at least 20 percent quicker than the 7700 XT, and often more than that. But the 7800 XT costs just 10 percent more than the 7700 XT. AMD's gaming graphics supremo, Scott Herkelman, justified that by saying, "$50 is a big deal for people who are looking at 7800 XT/7700 XT-class of GPUs."

But is $50 a "big deal" for people buying $500 GPUs? It's not totally inconsequential; it's pretty obviously 10 percent, which surely isn't that big a deal. Anyway, how AMD thinks that it makes sense for the more expensive GPU to offer better value I have no idea.

While this is something of an industry-wide trend with GPUs, one possible explanation with AMD's latest cards is that the company doesn't actually think it makes sense. Instead, the expensive chiplet packaging used by the Navi 32 GPU in both cards puts a lower limit on what AMD can reasonably charge and still make money, so the 7700 XT is priced at $449. Meanwhile, the 7800 XT has the opposite problem: a price ceiling imposed by AMD's own last-gen RX 6800 and 6800 XT cards, which can be bought either side of $500.

AMD's new 7800 XT is over 20 percent faster than the 7700 XT, but just 10 percent pricier.

The 7800 XT looks like it will at best match the 6800 XT, so it would be a tough sell for much more than the $500 that last-gen GPU currently goes for. So, $499 it is for the 6800 XT, just $50 more than the 7700 XT. For my money, that isn't anywhere near big enough a gap, and AMD must know that. But then the GPU market as a whole has simply stopped making sense. AMD's new GPUs only underline that frustrating fact.

Six raw 4K panels for breakfast, laced with extract of x86... Jeremy Laird eats and breathes PC technology.

© AMD

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> High-end server
> Update old Macs
> Linux desktop

Home server advice

I'm planning to build a replacement home server. My current server is on its last legs: a 4th gen Intel i7 CPU on an ITX ASUS board running Windows Server 2012 R2 Essentials. My server is used to back up my and my wife's laptop, plus run a Plex server.

I need one that's more modern and accessible online. I would like to stick with an ITX board and Windows Server, since I am familiar with it. Some of my mandatory requirements are: four or more SATA slots for 20TB of storage; the latest generation CPU that isn't a power hog; two NVME slots—one for the OS, and another for a scratch disk cache for Plex; 32GB RAM, and a possible Blu-ray burner. Wireless isn't required, as my home is covered with Cat 5e cabling.

I'd like to run one of the latest Windows Server Lite editions that allows remote access and a web address. I have family photos stored on the server, and usually give access to family members—the grandchildren use it to store artwork for example.

I started my love of servers after reading an article about the HP MediaSmart Server in your mag many years ago. It saved my bacon when my wife was going for her BSN and her laptop HDD failed. I was able to go to Comp USA, buy a new HDD, and within 90 minutes I was able to restore her laptop to the position it was in the night before the failure. My wife is an oncology nurse with 40+ years of experience.

—Ray Fletcher

THE DOCTOR RESPONDS: Our editor, Guy, addressed this in last month's Comments, but forwarded it to the Doctor for a detailed response. You could achieve most of what you need with our low-powered Ubuntu Server build from the September 2022 issue. However, your NVMe requirements rule out our favored low-powered choice: the ASRock J5040-ITX (around $150, www.newegg.com). It also means that you'll have to shop in the CPU range where the TDP is 65W, not a mere 10W, as found with the Pentium Silver range.

The key choices here are CPU and ITX motherboard. The 13th generation Intel Core i3 or i5 family will be your best bet when it comes to CPU, which means you'll need an LGA1700 ITX motherboard. We featured MSI's MPG Z790I EDGE Wi-Fi Mini ITX board in our 'Kick-Ass Micro PC' build in August 2023, and it ticks all your boxes, plus supports DDR5 RAM, but if the $360 price tag puts you off, take a look at its slightly less powerful sibling, the B760I EDGE Wi-Fi, instead—the DDR5 version can be had for $219 (www.newegg.com/p/N82E16813144596). The key differences are slower RAM (7200+ on the B760I, compared to 8000+ on the Z790I) and two M.2 slots instead of three, neither of which should be a problem. Get a breakdown of the differences between the two using MSI's comparison tool (www.msi.com/Motherboards).

The next question is which 13th-generation Intel chip do you pair with the board? In theory, Intel's T-series Core chips are the best for the job, because they offer a base TDP of just 35W. However, these chips are available on the OEM market only, so you're left sourcing regular chips instead. Of these, the Intel Core i5-13400 looks like a good choice. Although its TDP figures don't look that great compared to the T series (65W base, 154W turbo), if your server is idling most of the time or running background tasks, then the CPU consumes next to no power thanks to four of the i5-13400's 10 cores being E (for efficiency) cores.

After selecting your motherboard and processor, the rest of your system (RAM, NVMe drives, and so on) will follow on, which leads us on to Windows Server. The Home version of this was discontinued a long time ago, and the current entry-level version—Windows Server 2022 Essentials—is only available through OEMs. This means you'll need to purchase Windows Server 2022 Standard, which has an eye-watering four-figure MSRP that will dwarf the cost of your hardware.

Now might be a good time to reassess what you need from your server—the Doc suspects you can achieve everything you want through a regular Windows install (or—dare he say it—Ubuntu Server), combining native sharing tools with third-party services to achieve

↘ submit your questions to: doctor@maximumpc.com

what you want. Install Docker Desktop (https://www.docker.com/products/docker-desktop), and these services aren't just easy to set up and run, but can be made available over the internet via a suitable domain and reverse proxy like Nginx Proxy Manager.

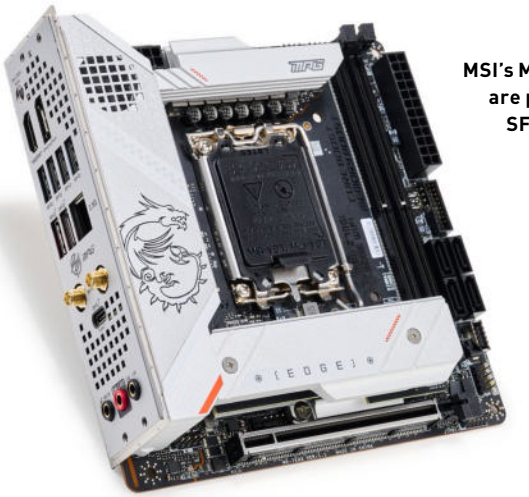
Resurrect old Mac

A friend has just passed on an old MacBook Pro—2016 vintage with Touch Bar—that runs well, but isn't supported by the latest version of macOS. What options do I have for keeping this running in the longer term when Apple stop providing any updates for the currently installled version (macOS 12, Monterey)?

—Jennifer Escobedo

THE DOCTOR RESPONDS: For now, you can keep your Mac running macOS Monterey with no major problems—most if not all existing software should run on it for as long as Apple support the release with patches and security updates. But guess what? You don't have to wait until Apple drops support for Monterey. Thanks to a tool called OpenCore Patcher (https://dortania.github.io/OpenCore-Legacy-Patcher), you can install a supported version of macOS (11 or later) on machines going back to 2007, and—more importantly—install the latest macOS 13 (Ventura) on your MacBook Pro.

It's simple to use—the app obtains a version of the macOS installer, then customizes it to your Mac model before creating a bootable USB flash drive that you can use to install the latest version of macOS on to your hardware. It's worth reviewing the support for your specific OS, as some features are known to be broken due to incompatibilities with older hardware. The OpenCore Patcher team can fix some of these with updates, but others remain unpatched and can affect system stability. This tends to be with much older hardware; right now, there's no mention of any specific problems affecting your 2016 MacBook Pro.



MSI's MPG mobos are perfect for SFF servers.

Switch Linux desktop

I enjoyed Jonni Bidwell's feature on breathing new life into an old PC by installing Linux on it (September 2023 issue). I went with the bog-standard Linux Mint install, but have struggled to get to grips with the desktop. What's the easiest way to preserve my settings and files before wiping the drive clean to try a different variant with another desktop?

—Troy Beatty

THE DOCTOR RESPONDS: While it's best practice to wipe your drive and start afresh with a new desktop, in most cases you can install two or more desktops side by side and switch between them. There can be glitches, though, meaning it pays to take a Timeshift snapshot before you begin so you can roll back easily if you hit trouble. It's also worth noting that desktops install their own apps like File Manager and Terminal client, so you'll end up with multiple shortcuts all doing the same thing.

The Doc recommends you try the desktop you want to switch to in a virtual machine like VirtualBox or from a live CD if one exists (check out Mint MATE or Mint Xfce editions) so that you don't end up installing loads of different desktops and breaking your installation.

Once you've settled on your new desktop, we recommend installing it through the Terminal after making sure your system is up to date ('sudo apt update && sudo apt upgrade'). For example, to install MATE:

```
$ sudo apt install mate-desktop-environment
```

Or to install Xfce:

```
$ sudo apt install mint-meta-xfce
```

Once the package has been installed, log out of your desktop. You'll see an icon appear to the right of your profile name on the login screen—click this, and you'll be given a choice of desktops. Select your new desktop, then log in. Look out for teething problems—on our test system, Xfce didn't display its Applications Start menu, which had to be manually added with other components by right-clicking the taskbar at the bottom of the screen and choosing Panel > Add New Items... Once added, right-click each item, and choose Move to reposition it.

Why no Windhawk?

As a long-time user of 7+ Taskbar Tweaker, I was disappointed to see you didn't feature it much in your taskbar tweaking tutorial (September 2023)—in particular, its website refers to a customization tool called Windhawk that claims to restore some of the tools missing tweaks in Windows 11. Is there a reason why you didn't feature this, and is it worth covering in more depth?

—Norman J Youngs

THE DOCTOR RESPONDS: We did look at Windhawk (https://windhawk.net) when researching the taskbar customization tutorial, intrigued by its tagline: "The customization marketplace for Windows programs". But it's this attempt to build a centralized marketplace for third parties to distribute their own mods that appears to have been its undoing, because after installing it, Bitdefender immediately threw up an alert.

We dug a little deeper into both vscodium.exe—which turns out to be a free and open-source implementation of Microsoft's vscode repository—and Windhawk itself to determine why Bitdefender considered it a possible threat. VSCodium has frequently found itself flagged by anti-malware tools, but while we were able to determine that this appears to be a false positive, a wider search on Windhawk did raise legitimate concerns.

These are based around how Windhawk works: mods are basically snippets of C++ that get injected into other programs, which depending on your point of view is either a great, convenient way to build a series of mods, or a security nightmare. The developer has attempted to allay concerns on Reddit (www.reddit.com/r/ReverseEngineering/comments/t9dd21/windhawk_the_customization_marketplace_for), and it sounds like an interesting concept. If the developer can work out how to allay security concerns and avoid triggering antivirus alerts, we may revisit it.

BEST VALUE GAMING PC

The best new mid-range AMD system?

WITH A POSITIVE outcome from our October 2023 build, the new budget AMD, we wanted to step things up with AMD's latest GPU, the Radeon RX 7800 XT. Pair this with the almighty Ryzen 7800X3D, and we've surely got a recipe for success on our hands. Yep, it's all-out AMD once more—this system should tackle the likes of the Intel 13600K & Nvidia GeForce RTX 4070 at a competitive price bracket. Sure, Intel and Nvidia capture the majority of the custom PC market, but no one should turn their nose up at AMD. They've not kept quiet, and with cheaper prices (on the whole), they put up a strong fight.

Although arguably the CPU/GPU are the two main components of a PC, the rest of the build is always fun to spec out. We're piecing together this machine in a very fetching case from BeQuiet. Usually, we don't like being told what to do, but they seem pretty adamant that we should zip our mouths and let the case do the talking. Terrible company name puns aside, the Shadow Base 800 FX from BeQuiet is a very pretty chassis to house our mid-range AMD system. It provides premium style, with form and function also at the forefront. In its white guise, it should pair perfectly with our NZXT N7 B650E motherboard. The RGB from the case and our TEAMGROUP T-Force Delta TUF Gaming Alliance DDR5 RAM should also pop in contrast to it, creating a strong glow inside and outside the case.

Costing around $2,000, we're hoping that this system is more than good enough to provide a solid QHD gaming experience with enough oomph to be a powerful productivity machine on the side, too. We know the latter is the most important, but we all want to know how this thing can game, right? We have high hopes, and should expect upward of 100 FPS running on ultra settings at QHD resolution—fingers crossed, anyway. –SAM LEWIS

INGREDIENTS

PART		PRICE
Case	BeQuiet Shadow Base 800 FX	$230
CPU	AMD Ryzen 7 7800X3D	$390
CPU Cooler	NZXT Kraken X73 RGB	$225
Motherboard	NZXT N7 B650E ATX	$317
GPU	AMD Radeon RX 7800XT 16GB	$499
Memory	32GB (2x 16GB) TEAMGROUP T-Force Delta TUF Gaming Alliance RGB DDR5-5200MHz	$90
SSD	1TB Solidigm P44 Pro PCIe 4.0 NVMe	$55
PSU	1000W NZXT C1000 80 PLUS Gold Fully Modular ATX	$180
OS	Windows 11 Home 64-bit OEM	$32
TOTAL		$2,018

PRICES CORRECT AT THE TIME OF PRINTING

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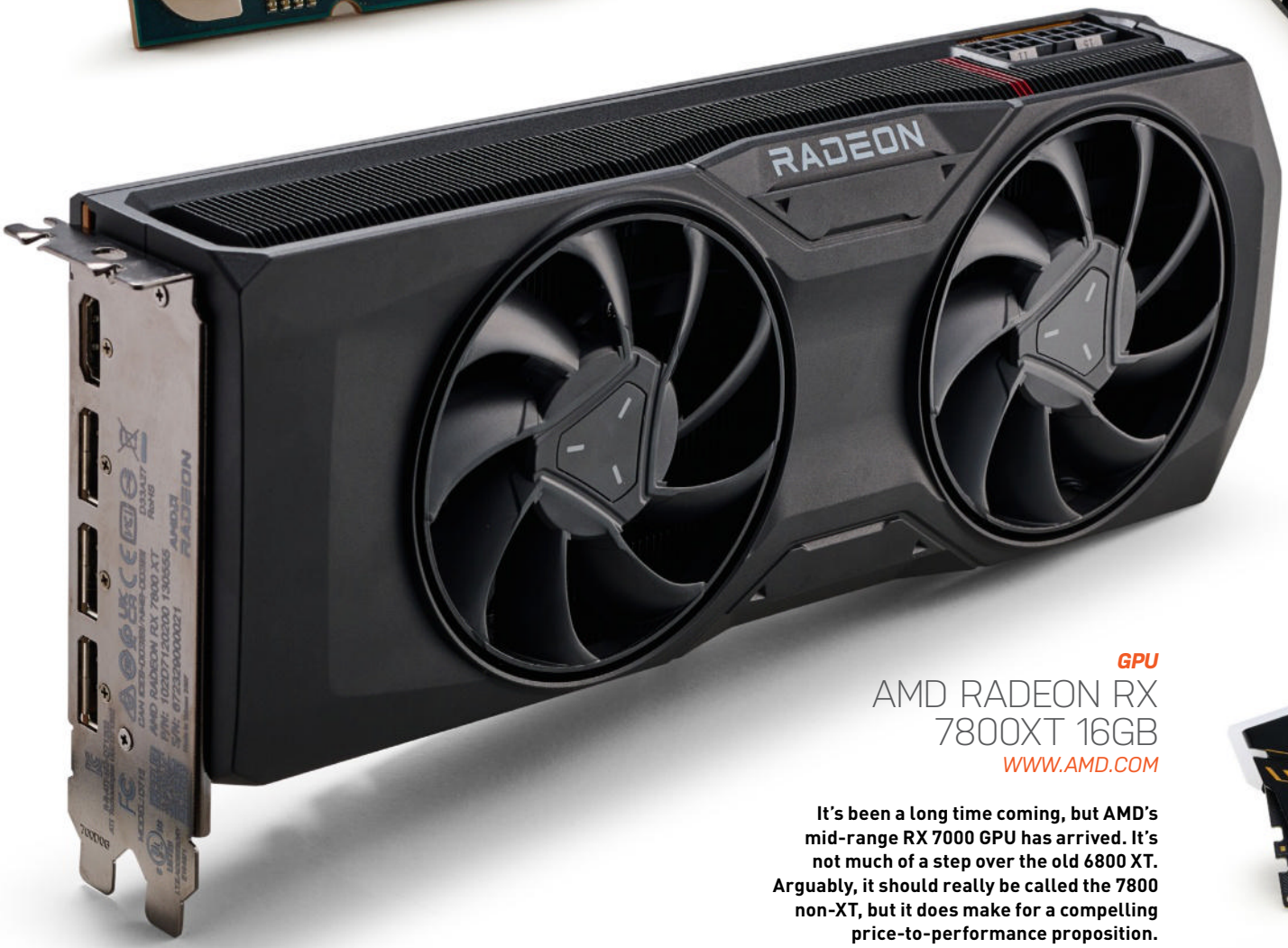
CPU

AMD RYZEN 7 7800X3D

WWW.AMD.COM

Theoretically, there are higher-spec AMD CPUs. In practice? Not for gaming. That's because of AMD's 3D V-cache equipped CPUs, only the 7800X3D has a single CPU die. The more expensive alternatives run an asymmetric dual-die config—one die with cache, the other without. That can compromise frame rates.

• $390



GPU

AMD RADEON RX 7800XT 16GB

WWW.AMD.COM

It's been a long time coming, but AMD's mid-range RX 7000 GPU has arrived. It's not much of a step over the old 6800 XT. Arguably, it should really be called the 7800 non-XT, but it does make for a compelling price-to-performance proposition. For most games most of the time, it's comfortably faster than an Nvidia RTX 4070.

• $499

MOTHERBOARD

NZXT N7 B650E ATX

WWW.NZXT.COM

If it's that slick Stormtrooper aesthetic that gets you going, you can't beat NZXT's fully-clad motherboards. Styling aside, this board doesn't get AMD's top X670E chipset, but the B650E gets the job done, including CPU and memory overclocking. The BIOS menu is easy to use, and the power-supply components are good quality.
• $317

MEMORY

32GB (2X 16GB) TEAMGROUP T-FORCE DELTA TUF GAMING ALLIANCE RGB DDR5-5200MHZ

WWW.TEAMGROUPINC.COM

90 bucks for 32GB of 5200MHz DDR5 memory? What a time to be alive. PC memory is now so cheap, you don't have to worry how much benefit there is of 32GB over 16GB. The upgrade is such a minor cost, it's an absolute no-brainer.
• $90

PSU

1000W NZXT C1000 80 PLUS GOLD FULLY MODULAR

WWW.NZXT.COM

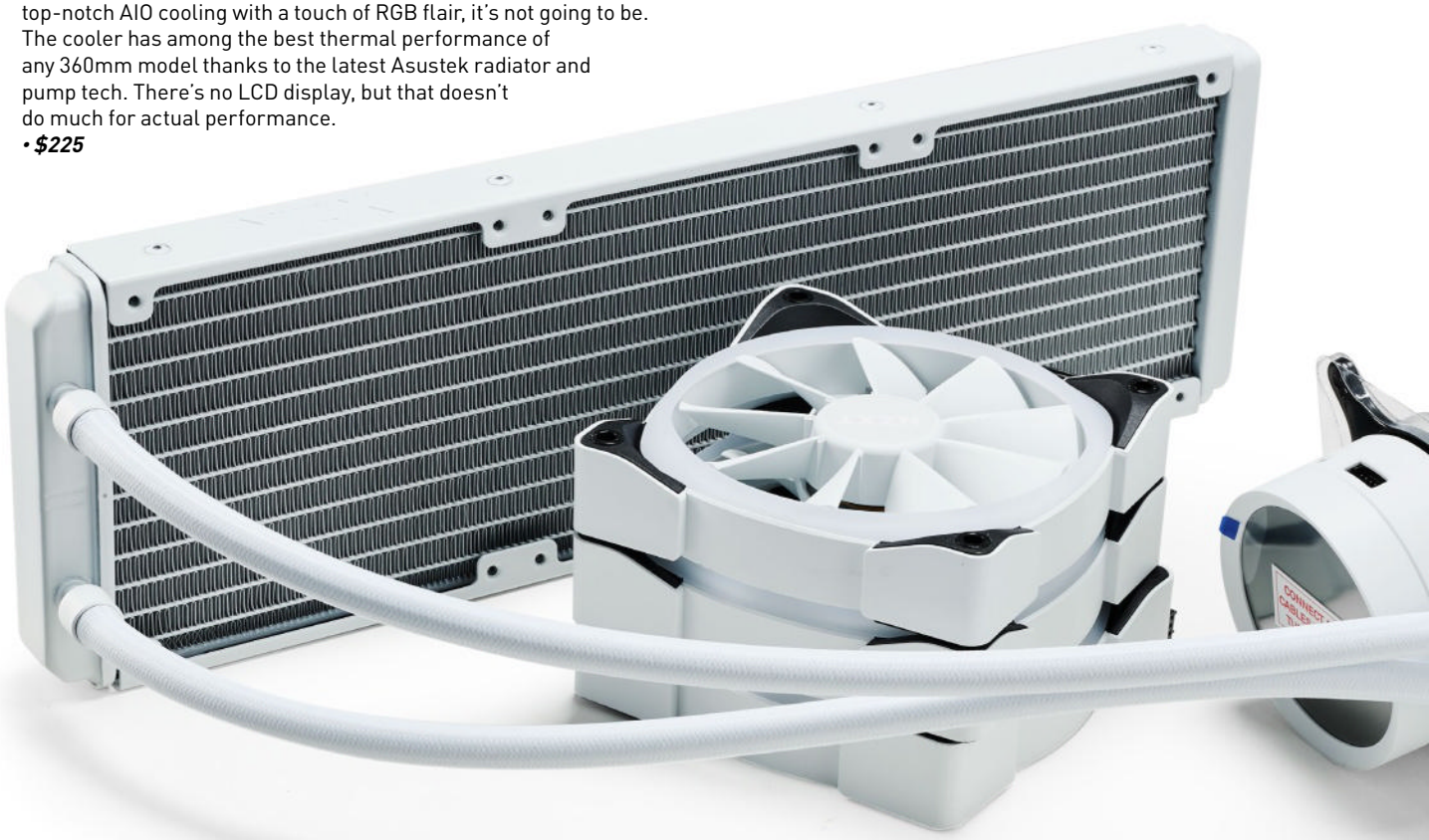
NZXT's 1000W beast comes with plenty of connectors, including up to six eight-pin PCIe graphics connectors. Of course, as a modular design, you only have to plug in what you need, keeping cable clutter under control. Built for NZXT by Seasonic, it's a quality item with a reassuringly long 10-year warranty.
• $180

CPU COOLER

NZXT KRAKEN X73 RGB

WWW.NZXT.COM

The NZXT Kraken X73 RGB isn't exactly cheap, but then, if you want top-notch AIO cooling with a touch of RGB flair, it's not going to be. The cooler has among the best thermal performance of any 360mm model thanks to the latest Asustek radiator and pump tech. There's no LCD display, but that doesn't do much for actual performance.
• $225



SSD

1TB SOLIDIGM P44 PRO PCIE 4.0 NVME

WWW.SOLIDIGM.COM

Solidigm is a relatively unfamiliar brand. However, it's actually part of the SK Hynix family. Make no mistake, there's serious engineering know-how behind this drive. Thanks to tumbling NAND memory prices, it's also crazy cheap for a 1TB drive with speedy PICe 4.0 specifications and 7GB/s of peak throughput.
• $55

CASE

BEQUIET SHADOW BASE 800 FX

WWW.BEQUIET.COM

With a beefy footprint but a minimalist vibe, the BeQuiet Shadow Base 800 FX offers plenty of internal space for building a seriously powerful rig. There's plenty of venting, fan brackets, and radiator location points for cooling, and the high-quality build and engineering makes for low overall noise levels.
• $230

AMD BUDGET GAMING RIG

7800X3D + 7800XT = ?

LENGTH OF TIME: **1-2 HOURS**

LEVEL OF DIFFICULTY: **EASY**

01 THE OUTER

At the start of it all, we find ourselves here, staring into the eyes of our empty shell, the BeQuiet Shadow Base 800 FX. Without its fancy covers and panels, it reveals what we'll be working with today—a multitude of cable channels, RGB-ness, and plenty of versatility. That's three positives right from the off.

To get here, there are thumbscrews for the side panels that loosen, after which you can simply slide back on the panels to remove them. Repeat this in reverse to re-install, but before then, we should really install some components, right? To remove the front cover, simply pull up from the bottom, being careful not to break any clips. In terms of fans, we are keeping them exactly where they are, as we will install our AIO at the top. Before we go any further, take your time to remove the panels and store them in a safe place.

02 THE CRANIUM

With our case stripped, we can put it to the side and start adding parts to our motherboard. Of course, everything has to connect to this, as it's the most fundamental part of the build, but we don't need to add it to the case just yet. It's much easier to add as much as we can externally. To begin, we need to carefully add in our CPU. The orientation of this is very important; on the motherboard and the processor are two triangles that need to face each other. Open the socket by releasing the retention bar on the side, then while holding the sides of the processor, align it in position and rest it down. Then, hook the retention bar back into place to secure the processor onto the motherboard.

03 WHERE YOUR GAMES GO

We love how this NZXT N7 B650E looks—there is no denying that it is a very sleek mobo. It comes with plenty of shrouds and heatsinks to hide any mess, and one of them is for the SSD. Whenever installing an M.2 SSD, try to use the uppermost slot that you can. To get to this, there is one Philips screw that we need to take off—the rest of the heatsink is magnetized to the board. It lifts off easily, after which we have access to the slot.

Place the connector end of the M.2 SSD into the port on the board at a 30-degree angle. Then, rest it down flat and use an M.2 screw to secure it in place. We can then peel off the heatsink cover and put this back onto the motherboard. Once again, secure it with the Philips screw. The drive is now hidden. More importantly, it is where it should be.

04 RANDOM ACCESS MEMORY

To add some more lighting to our system, and obviously to provide memory that is randomly accessible, we need to install our RAM. The easiest component to install by far, it doesn't take much to fit it in its slots. Always take a look at your motherboard manual first, but usually, if you only have two sticks, you'll have to use slots 2 and 4. These slots need to be opened up first by pressing on the clips. With these open, align the notches up on the sticks with the ones in the DIMM slots, and press down into place. A click will let you know that you've done things correctly.

05A AIO EP:1

With the RAM, SSD, and CPU secured onto the board, we can start by installing the AIO cooler. Without this, it wouldn't take long for our Ryzen 7 7800X3D to get pretty toasty. This first step requires the backplate bracket. This is a simple plate that lines up with the holes on the motherboard surrounding the CPU socket, allowing us to add a cooler.

Once that's on the back of the board, we can tighten it in using the AM4/AM5

01

02

03
SOLIDIGM.
P44 Pro
PCIe 4.0 NVMe M.2 SSD

04
T-FORCE
T-FORCE
DELTA
T-FORCE
DDR5 RGB

05a
AMD
RYZEN
AM5

bracket screws from the NZXT Kraken X73 cooler. These can be finger-tightened with the wider part at the bottom.

05B AIO EP:2

Now we have the bracket installed, we can add the fans to the radiator before installing it onto the case. We have to think about the positioning here, so take your time and plan where the fans will go and how you want them. The best option for us is to have the fans facing downward, as we'll be using this cooler as an exhaust system. It secures the radiator with the long screws and washers provided.

The other important thing to do here is attach the necessary cables. As these work in a daisy chain fashion, there are small cables that connect them together. Always refer to the manual, as it may look obvious, but it's best to check the ordering here before installing and finding out the hard way.

05C AIO EP:3

In the final episode of our three-part drama, we can install the fans and radiator to the top of the case. The most visually drastic change of all the steps, it's also the easiest, and only takes a handful of small Philips screws to keep in place. We rested the case on its back to help make this process easier, then positioned it so the pump side of the radiator was to the right as you look straight on. We also pulled the cables through the back of the case via one of the many cable channeling routes in this BeQuiet case.

06 2 BECOME 1

Aside from the GPU, we now have all of our components on our motherboard, and it's time to bring this and the case together. As much as the NZXT N7 B650E looks glorious, its white shrouding does create a small issue when installing it. You will certainly need a skinny magnetized Philips screwdriver to tighten this in place. It's very easy to drop a screw and then spend an equal amount of time finding it again. Sure, this happens on every build, but just take extra time with this.

You want to make sure you position the I/O panel of the motherboard into the slot at the back of the case first, then gently rest it in place and ensure the standoffs on the case line up with the screw holes. Then, using the case screws from the BeQuiet accessory box, tighten it down.

07A CPU HEADER

As the motherboard is in, we can go back to our cooling system for our build, the NZXT Kraken X73 RGB, and attach the pump header to the bracket. With most custom PC builds, it's important to choose the best route for your hoses to be—in most instances, this is out of the right-hand side. With the case laid on its back, we first need to add a small pea-sized amount of thermal paste onto our CPU. We positioned the pump in place and then used four large thumbscrews to tighten it to the CPU.

07B HEADER CABLES

The last NZXT AIO cables now need to be connected to the CPU pump header. These are the ones that are connected to the RGB fans on the radiator from earlier. It's pretty simple to identify what goes where—one is a Micro USB (annoyingly), and one isn't! Other than that, the CPU pump header cable needs to be attached directly to the motherboard. This is clearly labeled on the mobo, but always check the manual to be sure.

08A CASE CABLES

Continuing with wires, we're now going to hook up the BeQuiet Shadow Base 800 FX case cables to our motherboard. These include the USB cables, front panel power switch cables, and also the audio header. Without sounding like a broken record, the motherboard's manual will indicate where these cables will go. The two USB cables go on the right side of the board, and the rest situate towards the bottom of the mobo.

The pin connectors are quite fragile, so always attach slowly and make sure the orientation is correct before pushing it into position. We're very glad that the power switch cables aren't individual like they are in many cases—this helps us out massively and knocks around an hour of build time off. A slight exaggeration there, but you catch our drift!

08B FAN CABLES

To get our fans to spin and light up, we probably need to connect them, right? Well, there is no probably about it; it's inevitable. Thankfully, this Shadow Base 800 FX case has a pre-installed RGB fan header controller on the back of the case. We just need to connect this to the motherboard via the ARGB cable located at the bottom left corner of the mobo.

09 GRAPHICS, PLEASE

Something more exciting than cables is, of course, our fancy new mid-range GPU from AMD, the Radeon RX 7800XT. Installing this isn't too much of an issue, although we did have a

05b

05c

06

07a
be quiet!
TFORCE
TFORCE
NZXT

07b

be quiet!

08b

08a

slight initial worry. It wasn't clipping into the PCIe slot, but with some patience, it eventually did.

Before we got there though, we need to remove the second and third PCIe shroud from the side of the case by unscrewing the Philips screws that kept them in place. With these out of the way, we could then open the clip on the PCIe slot, in a very similar fashion to the DIMM slot clips for the RAM. Then, with the GPU in place after finally being able to clip it into the slot, we took the screws that held in the shrouds, and used these to secure the GPU to the case.

10A WE NEED POWER!

Right, everything is now in place, and we're itching to get this machine up and running, but there's just one thing we need: power! So to get going, we need to attach our NZXT C1000 to the bottom of the case. This Shadow Base 800 FX has a nifty bracket that makes this process slightly easier, and means that it's more compatible with other brands of PSU. So using three case screws, we screwed this onto our power supply.

10B IN IT'S RIGHTFUL PLACE

With the bracket firmly attached, the PSU can slot into the back of the case and sit flush. This bracket has four captive screws, so once the PSU is in, line the screws up and tighten it working diagonally and gradually. It will ensure even pressure is applied across the bracket. Now, we can turn our attention back to some more cables—we know, how many more can there be?

11 IN IT'S RIGHTFUL PLACE

Last but by no means least, the big power supply cables have to be added. Now, this was fairly straightforward. We didn't need a crazy amount of PCIe cables, only one for this 7800XT; it was the positioning of the CPU headers that was causing an issue. It took a long time to get this connected, and plenty of attempts. It was a tight angle to work with, but eventually we managed to get it in.

The 24-pin motherboard cable wasn't an issue thankfully, as this had plenty of room to the side for it to be channeled through. Around the back, we kept all the cables together with the included velcro cable management tabs. This ensured the back didn't look like a spider's web! Even though you're unlikely to see the back of your PC again, you get more peace of mind knowing that your system is tidy.

12 UPDATING OUR BIOS

We're going to get straight to the point here: we didn't need to update our BIOS, as our system booted up straight away. We went ahead and updated it, as on this NZXT N7 B650E ATX motherboard, it is super-easy to use the BIOS FLBK method.

Using a clean FAT 32 USB drive of at least 8GB of capacity, and another PC, head to the official motherboard product page and download the latest BIOS firmware from the support page. Take this file and extract it onto the USB. Rename the ROM file 'creative.rom', then remove any other file from the USB so that the 'creative.rom' is at the route of the drive.

Insert this into the motherboard's BIOS USB port, turn on the power without booting up the system, and then press and hold the BIOS button for three seconds. The indicator light will start to flash, and the BIOS update process will begin. Once the light stops flashing, you can then boot up your system. It should load into the BIOS screen.

13 ADDING WINDOWS

With a freshly updated BIOS, it's time to add our operating system to our AMD machine. Using another system, head over to the official Microsoft Windows 11 page and hit the download button under the 'Create Windows 11 Installation Media' part. Once it's downloaded, open the file and run through the software's on-screen instructions. When it asks where we want to install the OS, select your USB drive. We can reuse the USB drive from earlier, but we need to format this to FAT32 once more. Just a reminder: it needs to have at least 8GB of capacity.

With the file downloaded, we can safely eject this and insert it into a USB port on our new motherboard. Boot up the new system, and it should load into the BIOS. Here, we can change the boot priority order and make sure that USB is at the top of the list. Reboot the system, and then it should load into the Windows 11 installation wizard. Again, follow the on-screen instructions to customize your installation. After this, we can start to have some fun with our new PC.

14 AMD AUTO DETECT

Once inside Windows, it may seem that we are finally ready to get gaming, but hold it right there, because there are some vital updates and driver installs we need to do to get our PC running smoothly first. We can start by heading to the settings page, then system update. Hit the check button to find any updates, download any that are available, then restart your system.

After a Windows 11 update has been completed, we can head to the browser and install the AMD Auto-detect tool from the official AMD website. This will provide the most up-to-date chipset and graphics card drivers for our Ryzen 7 7800X3D and Radeon RX 7800XT. Here, you can also tune both the CPU and GPU to your liking and apply some of the latest AI tweaks, such as super resolution, etc.

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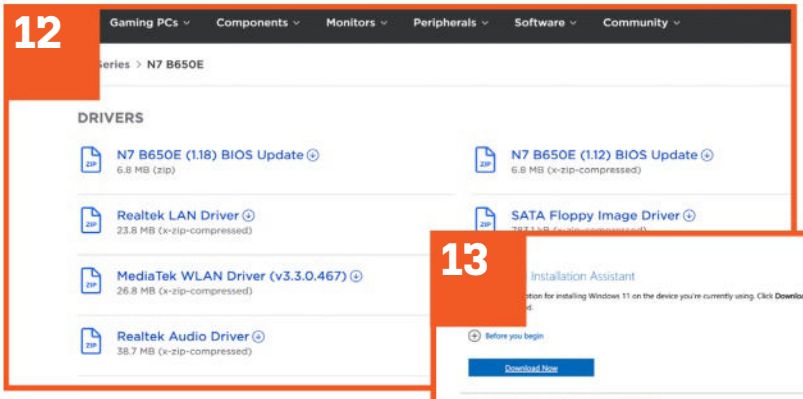
12
Gaming PCs
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Series > N7 B650E
DRIVERS
N7 B650E (1.18) BIOS Update
6.8 MB (zip)
N7 B650E (1.12) BIOS Update
6.8 MB (x-zip-compressed)
Realtek LAN Driver
23.8 MB (x-zip-compressed)
SATA Floppy Image Driver
MediaTek WLAN Driver (v3.3.0.467)
26.8 MB (x-zip-compressed)
Realtek Audio Driver
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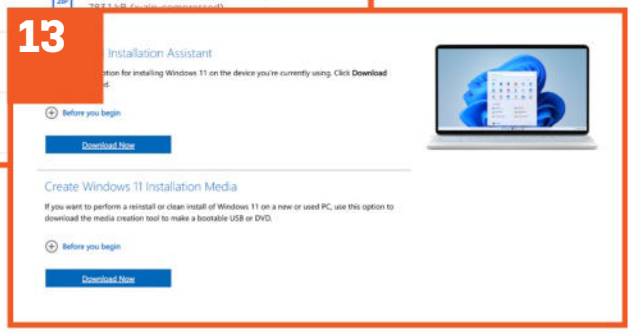
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DOWNLOAD WINDOWS DRIVERS

THE AMD 7800 RIG THE MOST BANG

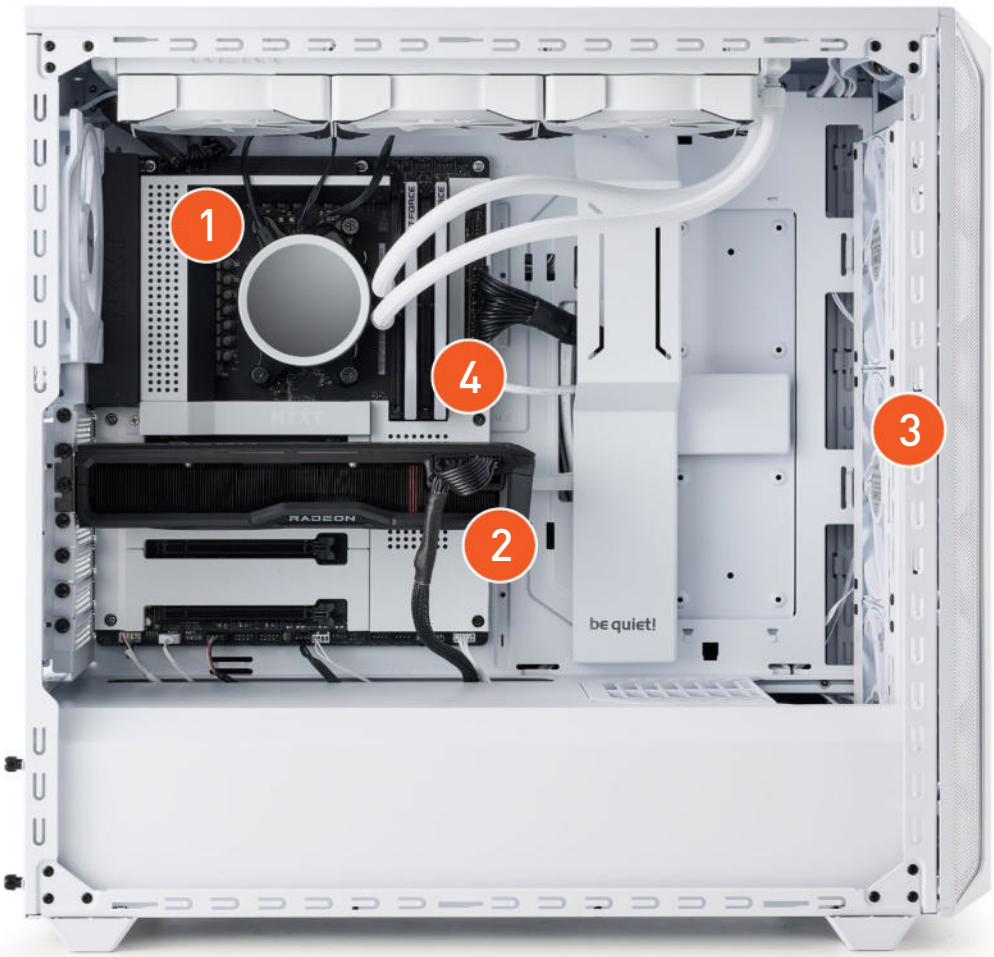
MOVING UP AND AWAY from recent budget machines, we wanted to create a more premium computer capable of solid QHD gaming, and also some intensive productivity on the side. We started this journey following an all-AMD route instead of the Intel/Nvidia path that we've done a lot of this year. When piecing together a custom PC, we need to start by mapping out the build and spreading our budget wisely. We knew we wanted to come in at around the $2,000 mark. and that we did.

Okay, we crept over ever so slightly over, but moving forward, we would make one change (component-wise) to rectify this. Our choice of NZXT's C1000 PSU was overkill, but our reason was for futureproofing this machine. You could get away with a 750W power supply, which would inevitably be cheaper, and bring our overall price point below the $2,000 mark. Other than the choice of PSU, we are very happy with the rest of the system. Performance was fantastic, but we go in-depth on that on the page opposite.

Visually, we're very happy with the overall styling here. The BeQuiet Shadow Base 800 FX is a striking case, with a clean interior and of course, the quiet RGB fans to keep it cool. The NZXT Kraken X73 RGB AIO also added more RGB to the mix and with its default white light setting, it illuminated the case inside to show off the rest of the system. The white N7 B650E mobo from NZXT matched perfectly with the Shadow Base 800 FX to create a seamless look. With its white shrouds, it hides a lot of the standard motherboard mess you'd usually get which creates this super clean machine. On the flipside, it's not perfect. The case cables match well, as they are white, but our PSU cables and the AIO cables don't match so well. It's a very small issue, but this change could completely clean up the system.

Physically building this system was a breeze. Taking between one and two hours, everything fell into place, and that's all down to the case's ease of use. There were plenty of cable routes, space, and easily accessible panels. This helps massively to keep the build tidy, and when you're tidy and organized, it makes the rest of the process easy. Although it looks like it could be quite a complex build, it was more on the beginner side. The pre-installed RGB fan controller on the case certainly helped as that can often be an issue.

The only slightly difficult part was installing the top-mounted exhaust fans and radiator. This was more time-consuming than anything else; it just required some extra planning to ensure that the airflow in the system was correct. So then, on the whole, this system went down like a dream, and looks the part, but how does it run?



1 The top of the CPU header is a bit of a mess, it's a shame one cable isn't enough here.

2 A white set of PSU cables would fit the rest of the build much more.

3 Instead of our NZXT X73 RGB being a top-mounted exhaust fan, we could have used it as an intake system at the front.

4 To match the theme further, white RAM sticks would have looked better. However, at least we can change the RGB to whatever we like.

-FOR-BUCK QHD MACHINE OF 2023?

THE ALL-IMPORTANT FIGURES

Following the success of the rest of the build, the performance of this all-AMD QHD gaming machine kept our winning streak going. We aimed for a PC capable of 1440P gaming at around the 100FPS mark, and that's what we have achieved. We decided to benchmark our system against the Tiny But Mighty PC from our August 2023 issue. This featured one of our favorite chips, the Intel Core i5 13600K, and the Zotac Gaming GeForce RTX 4060 Ti Twin Edge OC 8GB graphics card. That system came in at $1,656—cheaper than our machine, at $2,018. Saying that, the benchmarked system is a mini-ITX form factor, has a lesser-powered GPU, and doesn't have the same futureproofing this all-AMD build has.

The Radeon RX 7800XT performs better than the RTX 4060Ti and sometimes even better than the RTX 4070. The Nvidia RTX cards offer more performance when using some of the latest AI features, such as DLSS 3.0, but based on the box performance, it's clear that this 16GB Radeon RX 7800XT's performance is stronger than the RTX 4060Ti, but it does cost $100 more. On our *Cyberpunk 2077* test running at QHD and ultra settings, we scored an FPS score of 99, which is 36 percent better than the Tiny But Mighty machine at 73. On *Metro Exodus* running at the same settings, our build scored 21 percent more, and 34 percent more on *Total War: Three Kingdoms*.

Our FPS results ranged from 93 to 102, which is a healthy score at this resolution and settings. To gain further frames, we'd recommend playing at high settings at QHD for the best balance. Another score that impressed us when it came down to the graphical performance of the Radeon RX 7800XT was the 3D Mark Fire Strike Extreme score. We got a reading of 24,374—a whopping 60 percent better than the benchmark machine that scored 15,210. It's a clear win for the AMD 7800 XT system, but how about the other 7800, the Ryzen 7 7800X3D? Does that hold up against the mighty Intel Core i5 13600K?

The short answer is yes. Our Cinebench scores are similar, indicating an even performance between the two. The only differences we found were the pricing. The AMD chip comes in at $390, while the Intel competitor is $310, so a $80 difference, but not much of a performance gap. The Cinebench R23 Single-Core result on the AMD machine was 4 percent behind that of the i5 13600K. The Multi-core score was closer—only 1 percent—so it was tight, but we are going to have to give it to the Intel offering. Our system got one back though with the SSD performance and was 8 percent faster on read speeds, and 10 percent quicker with the write speeds. This AMD 7800 pairing puts in a good fight against team Intel and team Nvidia.

BENCHMARKS

	ZERO-POINT	
Cinebench R23 Single-Core (Index)	1,879	1,804 (-4%)
Cinebench R23 Multi-Core (Index)	17,957	17,792 (-1%)
CrystalDisk QD32 Sequential Read (MB/s)	6,808	7,343 (8%)
CrystalDisk QD32 Sequential Write (MB/s)	5,920	6,518 (10%)
3DMark Fire Strike Ultra (Index)	15,210	24,374 (60%)
Cyberpunk 2077 (fps)	73	99 (36%)
Metro Exodus (fps)	77	93 (21%)
Total War: Three Kingdoms (fps)	76	102 (34%)

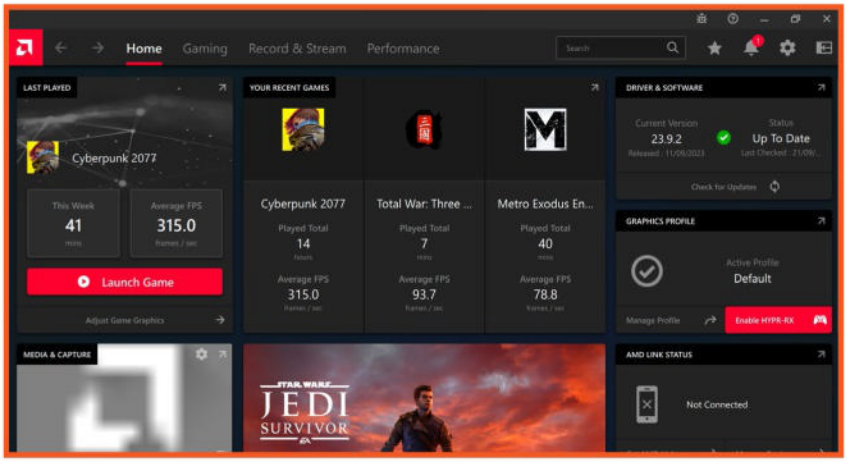
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of the Tiny But Mighty PC from our August 2023 issue with an Intel Core i5-13600K, a Zotac Gaming GeForce RTX 4060 Ti Twin Edge OC 8GB GPU, an MSI MPG Z790I Edge Wi-Fi Mini-ITX, 32GB of Corsair Vengeance DDR5-4800, and a 1TB SK Hynix Platinum P41 PCIe 4.0 NVME SSD. All games tested at 1440p 'Ultra' graphics presets. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

AMD AI TOOLS GET THE MOST OUT OF YOUR RYZEN AND RADEON RX GEAR

THE BENCHMARKING results from our system are pretty impressive, being able to run games at QHD resolution on ultra settings, achieving frame rates of around 100fps. However, there are a few very quick tweaks and improvements we can make using AMD tech to boost this further. We have to mention the competitor, Nvidia, as it has this sector of the market covered, with the likes of DLSS vastly improving game performance. That being said, AMD is snapping at its heels with what its own Software: Adrenalin Edition.

This application should be a necessity for AMD users, as it allows you to install the latest drivers and updates. You can also can fine-tune your hardware to squeeze some extra performance out of your PC for free. We'll touch on the one-click auto overclocking features later, but spoiler alert, it's one of the best ways to speed up your PC if you're an AMD user.



ADRENALIN EDITION

So here we are, on the landing page of the AMD Adrenalin Edition program. Without mentioning the Nvidia GeForce program too much, it's similar in that the home page features a game launcher, too. The AMD offering showcases more information, however, with details on the game's average FPS and how much time you've spent on each game. Now, this could easily be a warning sign, and sometimes we'd rather not know in terms of how many hours, days, or even weeks we've put into a game, but it could be a good indicator to limit your screen time. That's very adult of us to say, but even we have to be sensible sometimes. Scrap that; we love wasting our time on games, and so should you.

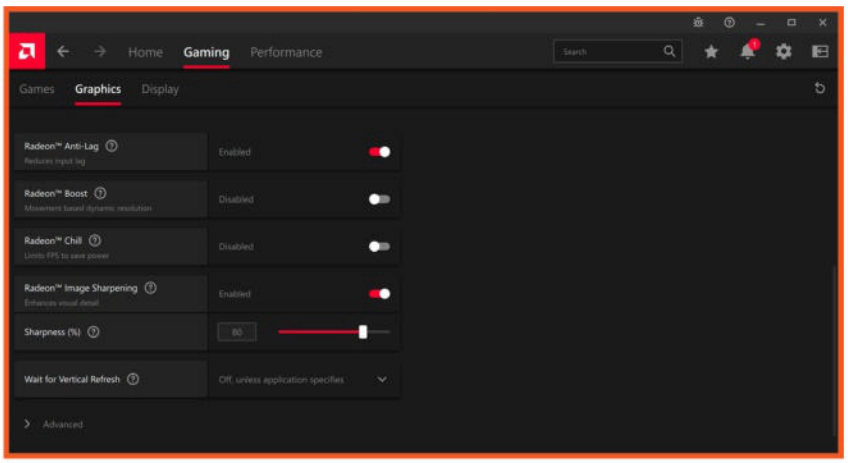
AMD AI PRESETS

From the home page, you can also choose a graphics profile and check the driver and software status to see if you are up to date or which version you are running. With the graphics profile, you can manage this and choose between a selection of presets that have been made for different needs. There is a default, power saving, quality, and performance mode.

The quality preset takes the most advantage of AMD's AI technology. It applies Radeon Image Sharpening, an algorithm that restores clarity via sharpening the image without increasing visual artifacts that usually occur with other methods of increasing graphical quality. There's a slider to adjust the strength of the sharpening. Under the quality preset, Radeon Anti-Lag is also activated, a feature that reduces input delay by dynamically adjusting frame timing. If you're after performance, this should be activated.

Talking about ramping up your speed, the performance preset doesn't apply Radeon Image Sharpening; just Radeon Anti-Lag. However, here, we would recommend turning on Radeon Boost. This only works in supported games, so it's best to check out which titles can take advantage of this tool first. Radeon Boost adjusts the resolution in real-time based on user input, with a minimal noticeable difference in the image quality. It works best when fps is uncapped and in GPU-limited scenarios.

You can also create a custom preset, which is handy if you want to fine-tune one for gaming, but don't want it to run all of the time. Before you load up your games, you could turn this on from the home page of the Adrenalin Software, and then load it into your favorite titles from there. Not bad, right?



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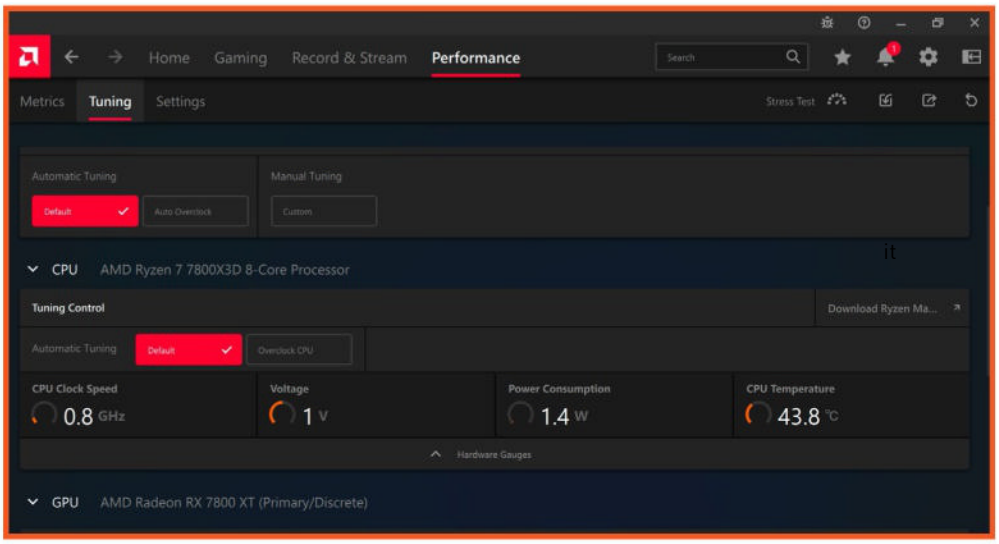


AUTO OVERCLOCKING

When you want to amp things up a notch, you can leave the home page and head to the performance section. With very little effort, you can take advantage of this AMD software by applying some auto overclocking to both your CPU and GPU (providing they're both made by AMD). Head over to the performance section of the application, and then to tuning. Toward the top, you'll see a generic automatic tuning option, which applies to both your CPU and GPU. Underneath that, you have the option to tune each individually. This is the more sensible option, as you may not need to tune your CPU and GPU at the same time, as this will cause a higher power draw and more stress on your system.

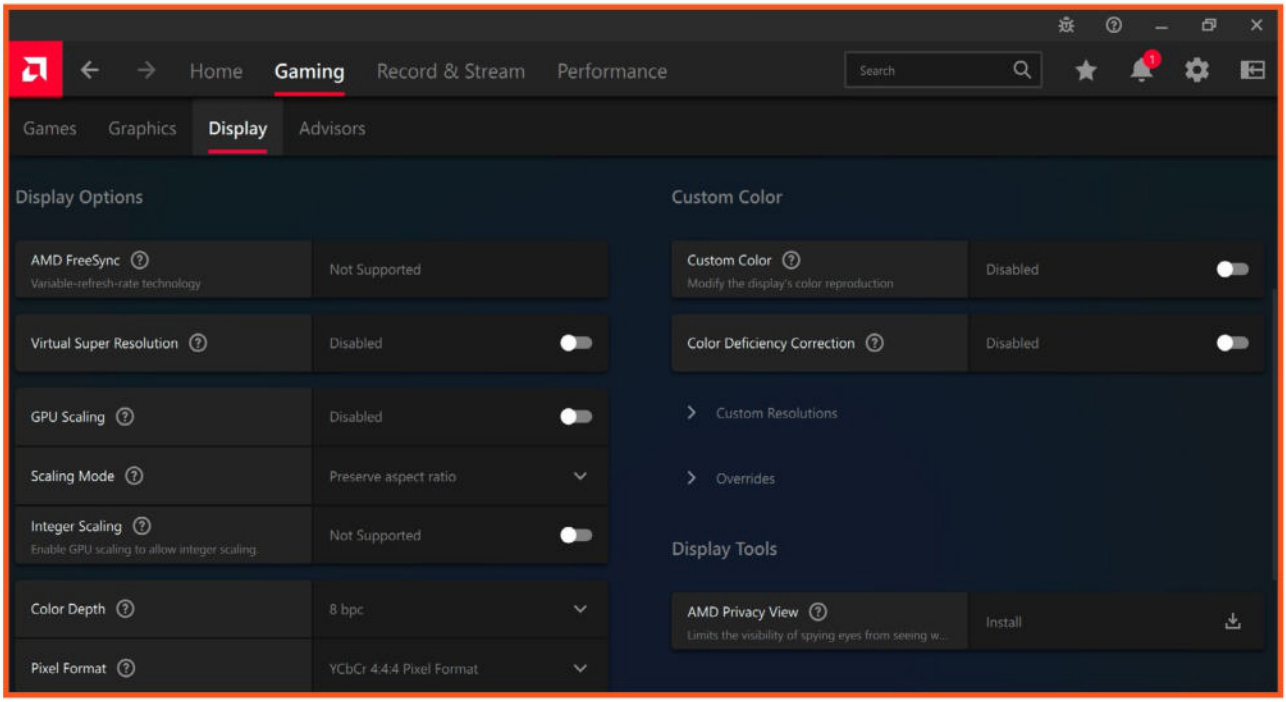
You can see the clock speed, voltage, power consumption, and temperatures here, too. It's important to research your hardware's limits as you never want to get too close to that maximum. You can also perform a stress test within the AMD Adrenalin software on the top right of this screen. This is an easy way to check the stability of the overclock you have just applied, and whether your system will be able to handle it or not.

DISPLAY TWEAKS

To further improve your gaming experience, you can play around with some of the display settings that this application has. AMD FreeSync requires a compatible FreeSync display, and is AMD's variable refresh rate technology. It aims to improve the smoothness of your display by updating as new frames are available to use. If you're experiencing screen tearing, stuttering, or juddering then this may help you out.

One of our favorite AI-implemented settings is virtual super-resolution (VSR). It emulates Super Sampling Anti-Aliasing in games that do not have native SSAA support. It creates a smoother image, with fewer noticeable polygons. It allows games to render at higher resolutions of up to 4K, then descales them down to a lower resolution. The aim here is to achieve 4K-like visuals, but on a 1080p or QHD display. The best part of all is that the performance is no different than if you were running on a normal 4K display, therefore you're vastly improving your resolution to a lower standard (1080p or QHD) with no real cost.

So if you've just pieced together an all-AMD system, then apply these tweaks where necessary to get the most out of your PC, and take full advantage of the capabilities AMD has to offer.



UPGRADING YOUR STEAM DECK STORAGE

2TB and 1TB M.2 2230 SSDs are readily available, and Jarred Walton shows you how to do it

We've seen numerous attempts at a handheld gaming PC over the years, but Valve's Steam Deck has suddenly taken the whole concept mainstream. It's not necessarily a Nintendo Switch replacement, but for PC gaming on the go, it offers a ton of potential. It might not be able to run every PC game under the sun, but it's definitely encouraging a lot of games to come out with "low spec" settings that are suitable for the Steam Deck's hardware.

The only serious issue with the Steam Deck is that it's lacking in storage. The base model comes with just 64GB of eMMC storage, with a $399 price tag. Bumping up to the top model gets you an anti-glare screen and 512GB of PCIe SSD storage for an additional $250. With plenty of games now surpassing the 100GB mark, we want more, and we're more than happy to save some pennies in the process.

Whether you're thinking of buying a Steam Deck or you already own one, or perhaps you're running an alternative like the Asus Ally, moving to a higher-capacity and higher-performance SSD might be the easiest upgrade decision you've ever had to make. Let's walk through the process and check what sort of performance improvements you can expect.

Valve's Steam Deck has taken the handheld PC gaming world by storm, but even the most capacious model tops out at just 512GB, and can quickly fill up.

VALVE'S EXPENSIVE STORAGE OPTIONS

Why all the fuss about upgrading your Steam Deck storage? There are two primary reasons. First, Valve overcharges for storage upgrades. Second, even the highest capacity Steam Deck lacks storage capacity.

The base model Steam Deck comes with a 64GB eMMC drive (basically an M.2 SATA drive), and costs $399. The next model up costs $130 more, and comes with a 256GB M.2 PCIe 3.0 SSD, while the final option costs $250, and comes with a 512GB M.2 PCIe 3.0 SSD and a "premium anti-glare screen."

Perhaps those prices might have seemed justifiable in 2021 when Valve first announced the Steam Deck—the pandemic was in full bloom, and supply chain issues were a huge problem. Two years later, such prices look ludicrous.

Hop on Amazon or Newegg, and you can find M.2 2230 SSDs ranging in capacity from 512GB to 2TB. 512GB drives start at less than $50, 1TB drives cost $70–$110, and various 2TB drives are now available for $150–$200. Are these as good as the one Valve uses? Almost certainly, as various teardowns on the web have found a smorgasbord of different drives and NAND chips. Many of the newer SSDs are even PCIe 4.0, though the Deck only supports up to 3.0.

You can make the argument that the Steam Deck doesn't need 2TB of storage, but you could buy the base model, upgrade it to 2TB, and still spend $100 less than Valve's 512GB model. You get a better screen, but the base screen has the same resolution, and works fine in our experience.

Going Below Deck

If you've ever dealt with upgrading the storage on a modern laptop, you'll know how difficult that can be. Often, you'll need to remove a dozen or more screws, sometimes peeling off the rubber feet to access hidden screws, and of course there's the dreaded "warranty void if removed" stickers. To make matters worse, some laptops even glue things like the battery in place. Thankfully, the Steam Deck has none of that.

There are numerous instructional videos and web pages, but you only need a small Philips screwdriver and a plastic "prybar" (also called a shim, jimmy, or spudger) to help pop the back off. Add in a bit of patience, and you're set.

For an SSD upgrade, remove the eight screws from the bottom of the Deck, then we recommend starting at the lower edge of the chassis (when looking at the screen) with your plastic shim, and working your way around. Once the lower edge is loose, move to the sides, and then the top edge. Take your time, don't force things, and search out some videos if you're having difficulties.

Once the back is out of the way, there's a metal EMI shield over the M.2 drive secured by three more Philips screws—and one of those is hidden behind some foil tape. Peel the tape back carefully so you can reuse it, and you should have easy access to the SSD. There's another EMI shield around the SSD itself, plus one last screw.

It's possible to swap out the triggers and thumb sticks as well, should you be so inclined, and this would be the perfect time to do that. Getting at some of the other bits and pieces can prove a bit more challenging, however, and if you're doing more than just upgrading the storage, you'll want to disconnect the battery. That takes quite a bit more effort, though, and you're more likely to damage something while doing that than to have the SSD swap cause problems.

Assuming you're not doing anything else, it's time to swap the SSD, reverse the process, and then check out Valve's Steam Deck Recovery Instructions (bit.ly/steamdeckssd) for how to image the new SSD. You'll need at least an 8GB USB Type-C compatible device for the image.

Valve created three different versions of the Steam Deck, but the top model only comes with 512GB of storage, while the base model has a puny 64GB drive.

Press and hold the volume down button while pressing the power button, and you'll end up at the Boot Manager screen. From there, it takes about ten minutes to get SteamOS running on the new drive.

Storage Expectations

Storage capacity is obviously the biggest reason to upgrade the Steam Deck SSD. Even better is that the Steam Deck tends to go on sale several times each year, typically during one of the Steam sales events. We've seen discounts as high as 20 percent, which would bring the price of the base 64GB version down to $320. But there are other reasons to consider upgrading, like performance.

Let's not get too carried away, though—the AMD APU that powers the Steam Deck isn't a performance monster. It's a 4-core/8-thread CPU based on the Zen 2 architecture, paired with eight RDNA 2 compute units, and it uses dual-channel LPDDR5 memory clocked at 5500 Mbps. It's a true custom design specifically for Valve, codenamed Aerith. The PCIe interface for storage is limited to PCIe 3.0 speeds, so up to 4 GB/s maximum.

As a gaming device, the GPU will be the primary limiting factor in most cases, with CPU performance as a secondary concern. Replacing the SSD can improve game load times, as well as the time it takes to re-image the Steam Deck, but gaming fps would only be affected in edge cases—for example, a bit less stuttering due to loading in assets.

We only have the 64GB eMMC that Valve used in the base model for testing purposes, as that's the Steam Deck that we purchased. It represents the worst-case scenario for storage performance, since it's effectively limited to PCIe 2.0 x2 speeds (500 MB/s). We tested seven

© FORESEE

The Steam Deck is an excellent example of a handheld that's designed to be easily serviceable, with just eight Philips screws and some clips securing the plastic shell.

other SSDs, all newer models that have PCIe 4.0 interfaces. They're all backward compatible with the Deck's PCIe 3.0 M.2 slot, and as M.2 2230 devices, you shouldn't expect amazing performance from any of the drives.

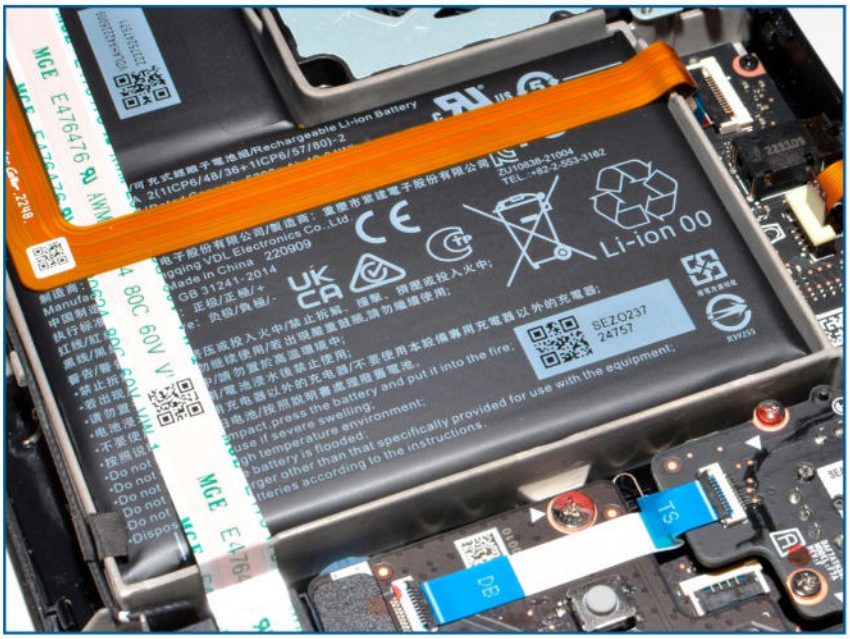
The reality of the Steam Deck is that you don't need amazing performance from the SSD. The main purpose is to play games on Steam. Downloading a large game might seem like something that could tax the SSDs, but in practice you'll be limited by the Wi-Fi connection. Valve uses a Wi-Fi 5 chip, or if you prefer, an 802.11ac 2x2 connection, which has been around for some time. The theoretical maximum transfer rate is 833 Mbps, but as with all Wi-Fi connections, in the real world you'll top out at around 550 Mbps.

Let's put that another way: 550 Mbps means downloading at less than 70 MB/s. Even a garbage SSD could write data at that rate until it's entirely full without breaking a sweat. Some of the faster drives we've tested can sustain 1000 MB/s write speeds on a desktop PC, but they'll almost never see that level of performance inside the Steam Deck.

Steam Deck SSD Performance

We've run a collection of benchmarks on the Steam Deck with the different SSDs, including timing how long it took to reimage the SSD (using a fast USB 3.2 10Gbps SSD as our source), and timing how long it took to complete the initial SteamOS installation after imaging. We checked some game install and launch times as well, but outside of the eMMC drive, there wasn't much worth mentioning. We tested certain things multiple times, and found that there was a relatively wide margin of error between runs, so we're focusing on the tasks that gave consistent results.

Besides testing general performance, we used KDiskMark to run some low-level SSD performance tests. It's basically like



High-performance SSDs have the potential to consume a lot of power, but the M.2 2230 drives we've tested aren't prone to guzzling current.

BATTERY LIFE

Battery life ranks as a very important metric for any gaming handheld. Depending on the games you play, the Steam Deck can last anywhere from around 90 minutes to as long as five hours or more. The more complex the game, mostly in terms of graphics, the shorter your battery life will be. 2D games, for example, generally provide much longer gaming time while your Deck is unplugged.

Battery life can also depend on hardware other than the AMD APU. One of our concerns with using higher-performance SSDs was if they might reduce how long you could game on the go. We ran some tests using *Shadow Knight*, a 2D platformer that shouldn't put too much strain on the Steam Deck's APU, to see how the SSDs fared. This represents something of a worst-case gaming scenario for the SSDs, as high idle power on a drive might severely impact run times.

We let the game run for an hour, with the thumb stick pushed right so that the Deck wouldn't go to sleep, and then checked how much battery life was remaining. Out of eight different SSDs, all of them ended up with 80–81 percent battery life remaining after our test. There's at least a one percent margin of error, which means they're all effectively tied. That means that the Active State Power Management (ASPM) and Link Power Management (LPM) in SteamOS are working as intended, putting the SSD into a low-power state when it's not busy, and thus prolonging battery life.

The Steam Deck has a 40 Wh battery, so average power draw was around 7.5–7.9 watts for the entire system in our testing. If you were to put in a drive that used 1W more power, you could shave off about 40 minutes of battery life. In contrast, the APU alone can peak at 25W of power use, which would cut battery life to under 90 minutes. In other words, the games you play will generally have a far greater impact on potential battery life than what SSD you happen to install.

STEAM DECK TESTING

	Foresee 64GB	Addlink S91 2TB	Corsair MP600 Mini 1TB	Inland TN436 1TB	Inland TN446 1TB	Sabrent Rocket 4 1TB	Sabrent Rocket Q4 2TB	Team group MP44S 1TB
SSD Controller	eMMC	Phison E21T	Phison E21T.00	Phison E19T	Phison E21T	Phison E21T	Phison E21T	Phison E21T
SSD NAND	TLC	Micron 176-Layer QLC	Micron 176-Layer QLC	Kioxia 112-Layer BiCS5 TLC	Micron 176-Layer TLC	Micron 176-Layer QLC	Micron 176-Layer QLC	Micron 176-Layer QLC
Re-Image Steam Deck (sec)	105.1	41.4	42.5	42.4	45.6	42.6	40.6	**40.4**
First OS Update (sec)	399.5	340.7	340.4	**326.3**	357.3	333.7	354.2	348.4
Boot to OS (sec)	34.2	27.2	27.3	29.2	26.6	**25.5**	26.7	26.7
Hollow Knight 1st Launch (sec)	18.9	12.1	12.0	12.0	**11.1**	11.4	11.2	11.3
KDiskMark Seq1T Read (MB/s)	268	2,327	2,199	1,652	2,256	**2,380**	2,293	2,293
KDiskMark Seq1T Write (MB/s)	189	1,568	1,448	1,435	1,474	**1,646**	1,633	1,578
KDiskMark Rand1T Read (IOPS)	4,856	15,072	18,755	12,336	17,401	**18,989**	15,096	15,309
KDiskMark Rand1T Write (IOPS)	6,800	64,168	64,305	61,427	57,444	63,545	**65,007**	64,097
SSD Temp (C)	**35**	54	59	65	61	57	59	60
Online Price ($/GB)	$15 ($0.234)	$174 ($0.087)	$90 ($0.09)	$80 ($0.08)	$80 ($0.08)	$90 ($0.09)	$200 ($0.10)	**$70 ($0.07)**

All testing was done with the base model Steam Deck that came with 64GB eMMC storage. Best results are in bold.

CrystalDiskMark, except for Linux. We're only reporting the queue depth 1 results, as those are most representative of real-world storage workloads, especially for the Steam Deck.

The biggest differences came from KDiskMark, where the eMMC drive looked slow. The worst of the SSDs we tested was at least six times faster on sequential read speeds, 7.5 times faster for sequential writes, 2.5 times faster on random reads, and over eight times faster on random writes. Based on those results, you might expect massive real-world performance differences, but it's not nearly as bad.

Launching *Hollow Knight* took about 50 percent longer, and the Steam Deck took 25 percent longer to boot from a powered off state. The initial re-imaging time was over twice as long as well, but the SteamOS setup process only took at most 22 percent longer than the fastest of the SSDs we tested. We also noticed that SteamOS updates, which seem to arrive every few weeks, took longer on the eMMC drive, but we didn't get exact results.

Temperatures ranged from 54C to 65C, with the older Inland TN436 that uses a Phison E19T controller running slightly warmer than the Phison E21T drives. The eMMC drive only showed a temperature of 35C, though we're not certain that's the actual controller temperature—the temperature never changed throughout our testing, no matter what we did. We wouldn't expect the drive to generate much heat, but sustained writes should at least change the temperature by a couple of degrees.

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DON'T FILL IT UP

Whether it's your PC, laptop, smartphone, or tablet, nearly every form of flash storage likes to have a bit of elbow room. That's especially true of QLC NAND devices, as they typically use a chunk of free space as a pseudo-SLC cache to speed up short-term performance. The Steam Deck is no exception.

We've tested all the drives in a nearly empty state, so the performance was as good as it's likely to get. As you use the Steam Deck and start to fill up the SSD with lots of games, you should expect things to slow down. Launching a game probably won't take much longer, but game installs and especially SteamOS updates can put a heavier load on the SSD, and might take two or three times as long.

Our general rule of thumb is to try to leave at least 20 percent of the available capacity free. That's not a concrete rule, though, and the type of NAND in the SSD plays a role. MLC and SLC SSDs are mostly a thing of the past, TLC now represents the performance choice, and QLC is the value NAND alternative. You might be able to get away with only 10 percent free space on a TLC drive, while on QLC you might even want to stay closer to 25 percent free.

If you do notice that your Steam Deck has started to take longer to boot and launch games, give your installed games list a perusal, and see if there's anything that can go. Freeing up 50–100 GB might be just the thing to restore some of the lost performance.

The reality is that most things you'll do on the Steam Deck are going to be sufficiently fast. 19 seconds to load *Hollow Knight* versus 12 seconds isn't the end of the world, especially considering there's another 12 seconds or so delay due to navigating the menu and screen transitions. From Steam to actually playing, then, it's more like 32 seconds versus 24 seconds. Other games take longer to load, but the CPU processing of data will often be a limiting factor. You can't even try to install any game that's larger than about 45GB on the eMMC drive, as the OS uses the remaining space.

Limited M.2 2230 Choices

One issue that you'll find with upgrading the Steam Deck storage—or any other device that uses an M.2 2230 drive—is that there aren't a lot of options. There are hundreds of M.2 2280 drives out there, in capacities ranging from 128GB to 8TB; 2230 options pale in comparison.

We sourced seven recent model drives, along with one slightly older model. Nearly every SSD used the Phison E21T controller, except the older TN436 that used the previous Phison E19T. The same story applies to the NAND: every current drive used Micron 176-layer TLC or QLC NAND, while the older TN436 used Kioxia 112-layer TLC. Considering the hardware, you'd expect nearly identical results from most of the drives, though firmware differences can show up.

There are also a few older 2230 drives, plus a few recent launches, like the WD SN770M. WD might have an in-house controller that provides some differences in performance relative to the Phison-based drives, but it's being tight-lipped about the hardware. Regardless, if you're planning to use one in the Steam Deck, any potential performance advantage isn't likely to matter.

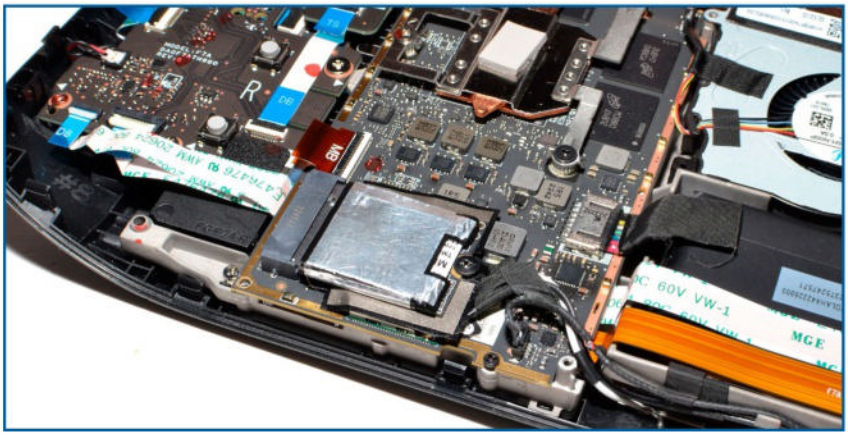
Due to the limited number of 2230 drives currently available, prices tend to be much higher than other SSDs. You can get a top-performing 2TB M.2 2280 drive for around $120, for example, while the lowest priced 2230 2TB drives cost over $50 more, and are most definitely not as fast. For single-sided 2230 drives, which is what the Steam Deck and most other devices require, you're also going to be limited in terms of maximum capacity.

Grabbing a 2TB drive is your only option if you want maximum capacity—M.2 2230 drives with more than 2TB don't exist right now. If you're more interested in the best value based on price per GB, the Teamgroup MP44S 1TB drive costs $70, or seven cents per GB. Note its use of QLC NAND, where the $80 1TB drives use TLC NAND. Even at $70, that's about double what you'll pay for the least expensive M.2 2280 SSDs: 2TB drives currently start at $66, and 1TB drives start at just $33.

The good news is that prices are starting to come down, thanks in part to the Steam Deck, as well as competing devices like the Asus Ally. A price premium will likely still exist, but we'll hopefully start seeing new 2230 drives priced at five cents per GB or less in the future.

Waiting for Steam Deck 2.0

Valve's Steam Deck created quite the hubbub at launch, and people had to order months in advance back in 2021. That's no longer necessary, and you can order one today and have it within a week or two—or find them at Amazon, though that's



There are hundreds of M.2 2280 drives, of which we tested seven recent ones here

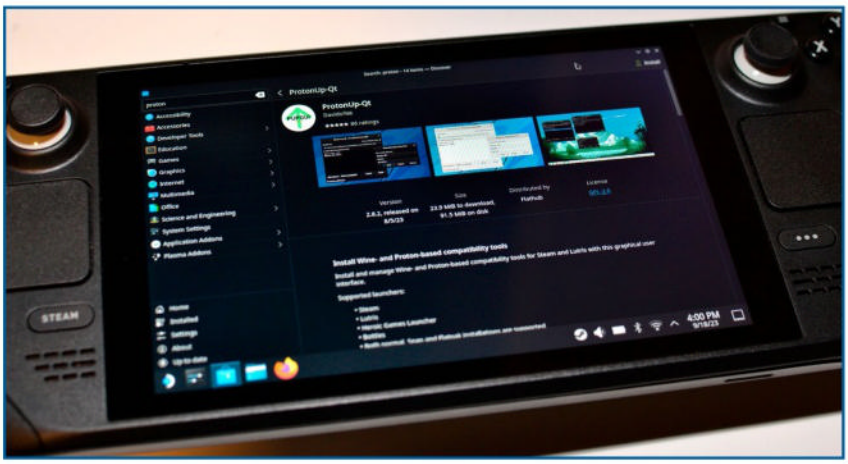
through third-party resellers that have increased the prices. But as good as the Steam Deck is, it's over a year old now, and we'll probably get a version 2.0. That might be worth waiting for if you haven't already taken the bait, but it may not happen for a while.

There are other handhelds, though none feel as polished as the Steam Deck. The Asus Ally came out earlier this year, and on paper it looks superior in a lot of ways. It has more CPU and GPU cores available, using AMD's newer Zen 4 and RDNA 3 architectures. That should give it a significant performance advantage, though it also drives a higher-resolution display. In practice, you'll sacrifice battery life if you force performance mode while unplugged, while the default power profile is only slightly faster than the Steam Deck.

The Ally also costs a lot more than what you'll pay for a base model Steam Deck plus an SSD upgrade. It's $700 for the Z1 Extreme processor (8-core CPU and 12 GPU compute units) and a 512GB SSD, or $600 for the far less capable Z1 processor (4-core CPU and 4 GPU compute units) and 512GB SSD. Valve clearly has the advantage in that it can subsidize the cost of the hardware with the money it makes from selling Steam games, though the Ally proves competitive overall.

Considering Valve is reportedly on track to have sold over 3 million Steam Decks by the end of the year, an updated model must be in the works. There are also plenty of newer games that struggle to run at reasonable speeds on the current Steam Deck, even at minimum settings. Updated hardware could help address such deficiencies. It's not so much a question of if, but when, and that could be as soon as 2024, or Valve could wait a few more years. Sure, the current Steam Deck may struggle in some games, but there are thousands it can run just fine.

Ultimately, Valve isn't talking about a sequel yet, and it probably won't until the new hardware is close to completion. But whenever that day comes, we'll be eager to see what the new model has to offer. Hopefully part of the package will include a lot more storage capacity by default.



Linux gaming has improved by leaps and bounds over the past decade, and Valve's Proton software now supports a huge number of PC games.

LINUX & PROTON

Valve's new handheld has also done more to spur adoption and support for Linux gaming than any other system we've seen. Tons of servers already run Linux, but after the failed Steam Machine and SteamOS initiative from 2015, it felt like Windows might remain the only viable PC gaming solution. The Steam Deck gives SteamOS a major kick in the pants, and proves that you don't need Microsoft Windows.

A key aspect of gaming on the Steam Deck involves Valve's Proton software layer. Proton builds off the existing Wine (Wine Is Not an Emulator) translation layer, and it first became available in 2018. Five years later, the level of support for new and existing games continues to grow.

At its core, Proton translates Windows graphics API calls—DirectX 9, 10, 11, and 12—into comparable API calls for Linux. These go through DXVK (DirectX-to-Vulkan), and depending on the game, performance can at times beat native Windows performance for the Steam Deck's hardware.

Of course, you don't have to use SteamOS if you prefer Windows. You can install Windows 10/11 on the Steam Deck if you prefer, opening up full compatibility with games that aren't available on Steam, not to mention games that use DRM that won't work with Proton.

Having tested both, we prefer the native SteamOS experience. Windows simply doesn't work very well on smaller screens, and trying to use the touchscreen or touchpads gets a bit finnicky. But if you follow our advice and upgrade to a roomy 2TB SSD, there's another option: just dual-boot SteamOS and Windows. Then, you can fall back to Windows if you encounter a game that doesn't work with SteamOS. Just note that you'll end up with SteamOS and Windows partitions on your SSD, and you can't "share" game installation files between the two operating systems.

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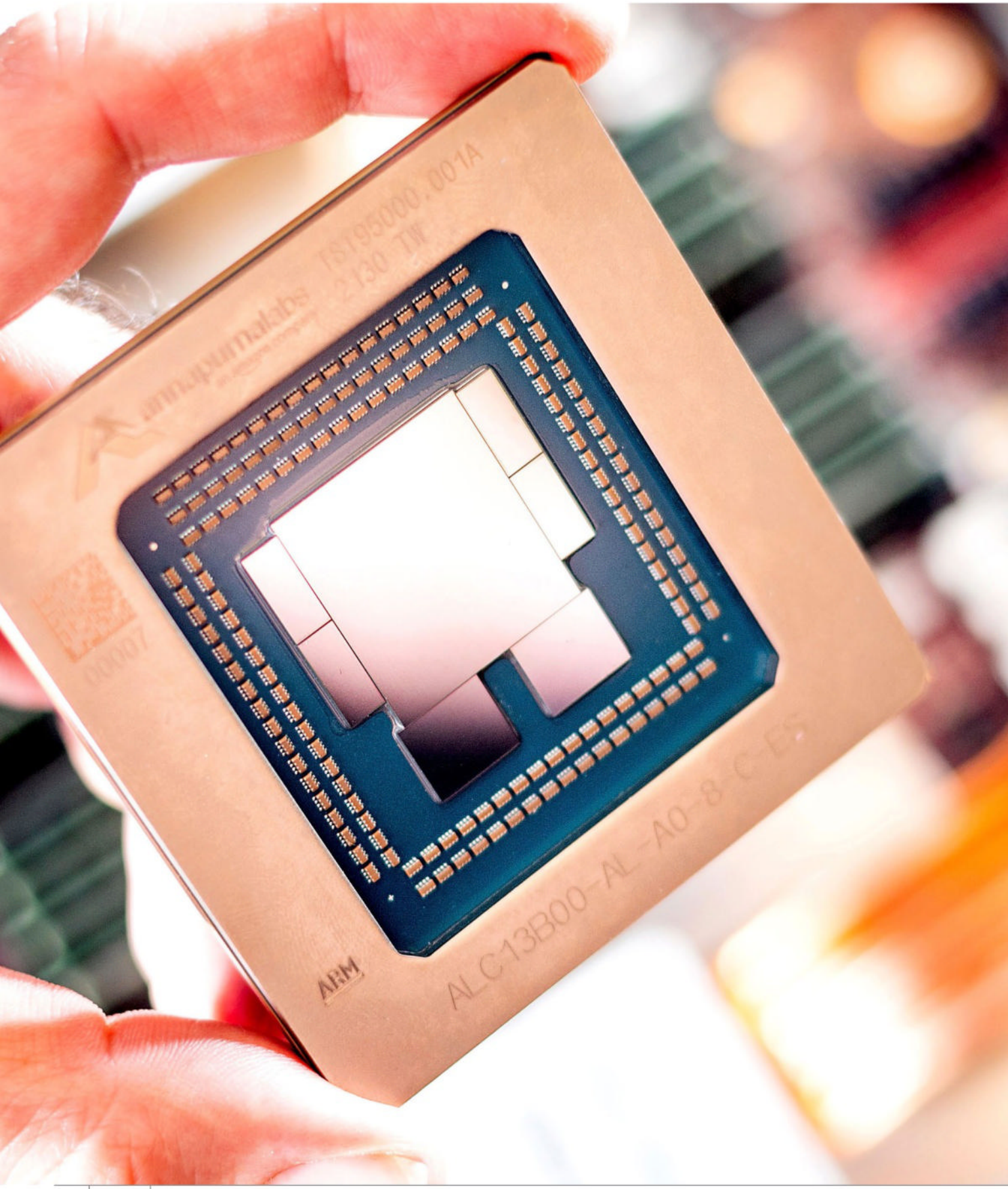
Amazon's Graviton server chips run high-performance Arm cores.



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ARM VERSUS X86

THE END OF AN ERA

Is it a case of when—not if—Arm chips replace x86 CPUs in our PCs? *Jeremy Laird* investigates, and wonders whether the very question is outdated in an age of AI and heterogeneous and open-source computing

When it comes to power efficiency, Arm-based CPUs have set the standard for decades. But for pure performance? Accept no substitute. You need a proper x86 chip—at least, that's how the classic Arm versus x86 CPU contest used to stack up.

In the here and now? It's not quite so simple. CPUs based in Intel's x86 instruction set still top the performance charts, at least in the consumer space. But when it comes to the performance per clock cycle of a single CPU core, the very latest Arm chips arguably have the edge.

In fact, Apple now makes Arm CPU cores so powerful that its iPad Pro offers comparable single-threaded performance to a high-end desktop PC processor. Indeed, Apple's latest Arm-based CPUs are so good, they can beat native x86 processors when running x86 code. That's ridiculous, and it begs some pretty pressing questions about the long-term viability of x86.

In short, is Arm now proving not only superior when it comes to power efficiency, but equal to or better than x86 as a platform for pure performance? If it is, should and indeed will Arm chips eventually replace x86 in PCs? And does Intel's new IDM 2.0 strategy that prove even it knows the end is nigh for x86?

FAILURE OF ATOM

If Arm processors do eventually assimilate the PC, replacing Intel's venerable x86 CPUs, hindsight will reveal that the seeds for x86's ultimate demise—and possibly Intel's, too—were sown by the failed Atom project. Atom was the low-power chip that was meant to get x86 into smartphones, and it was an abject failure.

Had Intel managed to turn x86 into a competitive ultra-mobile architecture for smartphones, not only would the company be dramatically richer and more successful, but x86 would also look much more viable for the future. So was the failure of Intel's move into smartphones a function of x86's fundamental unsuitability for the most low-power of general purpose applications? Or did Intel just mess things up?

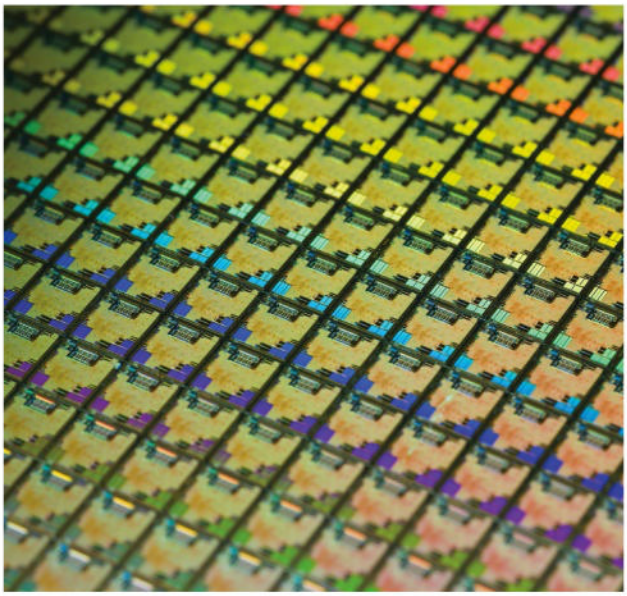
In 2012, the first smartphones running an Intel x86 chip went on sale. Models like the Lava Xolo looked pretty plausible for the day. It had a high-resolution screen, 1GB of RAM, 16GB of storage, hardware video decode supporting 1080p video playback, multiple cameras—the works.

It also ran Android on its 1.6GHz Intel Atom Z2460 CPU with a decent SGX540 GPU, a chip otherwise known under the Penwell codename. To put this into context, in 2012, Apple was transitioning from the iPhone 4S to the iPhone 5. It just so happens that the Apple A6 chip in the iPhone 5 was the first to use cores designed in-house at Apple rather than off-the-shelf cores licensed from Arm, albeit the A6's "Swift" cores were still very much based on the Arm instruction set.

Atom was single-core and HyperThreaded where the Arm competition in the Apple A6 and Qualcomm Snapdragon S4 were dual-core. But by 2015, Intel had a quad-core Atom chip running in handsets like the Asus Zenfone 2, complete with a 5.5-inch 1080p screen and 4GB of RAM. Performance-wise versus competition like Apple's iPhone 6 or the Google Nexus 9, it was a bit of a mixed bag. But the overpicture, including battery life, was far from a disaster. In other words, it's hard to argue that the x86 instruction set and the perceived baggage it brings is what did for Intel in smartphones.

Yet by April 2016, Intel had officially cancelled Broxton, its then-upcoming quad-core SoC for smartphones, in effect putting an end to its efforts to get into smartphones. So what happened? Part of the problem was that Qualcomm, the biggest player in customer smartphone SoCs, was making it very hard through various licensing and purchasing terms for smartphone makers to experiment with Intel chips.

Given Intel's record for sharp practices when taking on the likes of AMD in the old-school x86 market, you could argue that Intel got a taste of its own medicine. At the same time, the two biggest players in the smartphone market, Apple and Samsung were focussed on using their own SoC designs in smartphones, effectively ruling them out as customers for Intel SoCs. The combined consequence was that Intel's potential customer base for smartphone chips was awfully narrow, at least without a costly and drawn-out battle with Qualcomm.



The success of Arm chips is arguably as much to do with TSMC's process tech as any inherent advantage over x86.

> The other major factor in Atom's failure involved Intel's manufacturing technology

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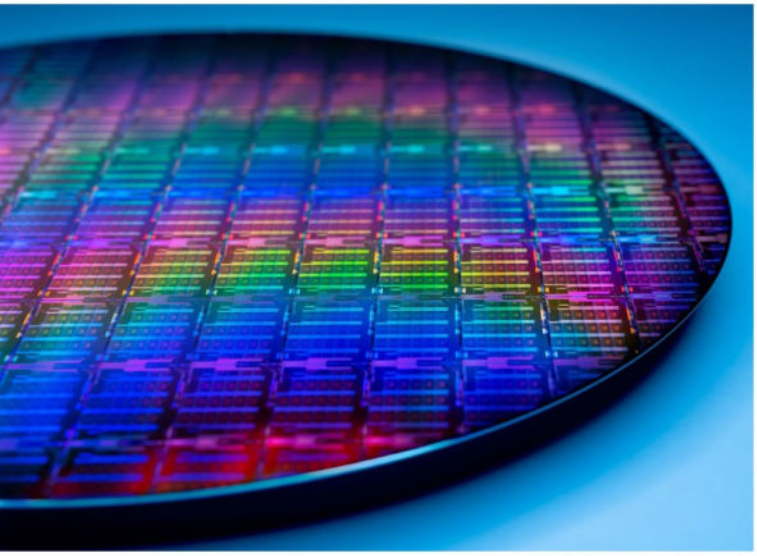


Intel's x86 CISC cores have traditionally offered higher performance.

The other major factor in Atom's failure involved Intel's manufacturing technology, which turned out to be compromised on multiple levels. Coming into the smartphone era, Intel's status as the most technologically advanced player in silicon lithography, the technique used to produce the integrated circuits in nearly all modern computer chips, was just beginning to falter. Here we are over 10 years later, and Intel still hasn't recovered its leadership position.

Back in 2012, for instance, Intel was then expecting to be cranking out 10nm chips by 2016. But as we now know, that turned out to be extremely optimistic. Even before Intel's 10nm woes, its 14nm node suffered significant delays, but 10nm turned out to be a disaster. It wasn't until early 2020 that 10nm Intel processors were available in any true volume, and even then they were limited to laptop processors. Moreover, even now in 2023 and fully seven years after 10nm was supposed to come online, the 10nm node revised and rebranded to Intel 7 is the most advanced silicon you can buy from Intel.

INTEL FALLS BEHIND

While this was happening, Taiwanese mega-foundry TSMC, the company that produces the majority of the world's smartphone chips, not to mention both Nvidia and AMD's latest GPUs, plus AMD's CPU dies, was really getting into its stride. Historically, TSMC had always been a node or two behind Intel. But Intel's stumbles with 14nm and then 10nm allowed TSMC to not only catch up with Intel, but comfortably overtake it.

Today, TSMC has just begun to produce chips for Apple's upcoming iPhone 15 on its 3nm node, known as N3. It's debatable exactly how TSMC N3 compares to Intel 7 or Intel's next node, Intel 4, which supposedly comes online later this year. But most industry analysts agree that TSMC is at least one node ahead.

Anyway, the point here is that using the most advanced nodes for both power efficiency and to reduce chip size is critical for smartphones. Intel ought to have had an advantage back when it was trying to break into smartphones with Atom, but those ambitions just so happened to coincide with the process node struggles that continue to this day. As if that wasn't enough, Intel

© INTEL

RISC VERSUS CISC

WHAT'S IN AN INSTRUCTION SET?

Strip the x86 versus Arm contest down to its essentials, and you arrive at instruction sets. Neither x86 or Arm are CPU designs or architectures. Indeed, Intel and AMD produce their own bespoke CPU core designs. They share compatibility with the same x86 instruction set, which dates back to Intel's 8086 CPU of 1978, and has been revised and extended.

Exactly who owns and controls the x86 instruction set is a tricky question that's been tested in courts across the globe for decades. But thanks to a raft of cross licensing arrangements and court decisions, what matters is that only Intel and AMD are licensed to manufacture x86-compatible processors.

Arm, by contrast, is more narrow and broad. The Arm instruction set has likewise been developed and refined, but is owned and controlled by UK outfit Arm Holdings. However, unlike x86, which was meant to be the sole purview of Intel and never intended to be licensed to the likes of AMD, the whole point of the Arm instruction set is for third party licensing.

Indeed, Arm doesn't produce processors. What confuses the comparison is that Arm does create processor core designs that can be licensed. But at base level, the Arm instruction set can be licensed and used as the basis for bespoke processor designs. That's what Apple now does, having previously bought in Arm's CPU designs until the A6 chip in the iPhone 5 introduced Apple's first full in-house design.

Anyway, putting aside the specifics of actual CPU designs, there's a much more fundamental and important difference between x86 and Arm, and it boils down to RISC versus CISC. Respectively, they stand for Reduced Instruction Set Computing and Complex Instruction Set Computing.

An instruction set acts as an interface between software and hardware. Up to a point, the clue is in the name with RISC and CISC. RISC's instruction set uses less power, while CISC's more complex sets enable more performance. Arguably both x86 in its current 64-bit implementation and the latest iteration of Arm's instruction sets are hybrid, with elements of both RISC and CISC. But in broad terms, Arm remains predominantly a RISC instruction set and x86 CISC.

That means that x86 CPU cores are larger, more complex, and more power hungry, while Arm cores are smaller and more efficient. More recently, CPU designs compatible with these two leading instruction sets have been converging, so it will probably be factors other than inherent performance and efficiency that decide how this all plays out.

DO CPU CORES STILL MATTER?

WHY HETEROGENEOUS COMPUTING SOMETIMES MAKES CPU POWER IRRELEVANT

Is this entire discussion about x86 versus Arm missing the point? In an important regard, yes, because the future of computer chips is almost certainly heterogeneous. In that context, whether they're x86 or Arm isn't really relevant. That's because the x86 and Arm instruction sets largely apply to general purpose CPU cores, but increasingly, those only make up a fraction of a given computer chip's functionality.

Already, it's common to have hardware accelerated graphics separate from the CPU cores in a GPU, which in most PCs is integrated into the same silicon as the CPU. But more recently, additional functionality is finding its way into the same silicon die, or at least into the same multi-chip package. This is heterogeneous computing.

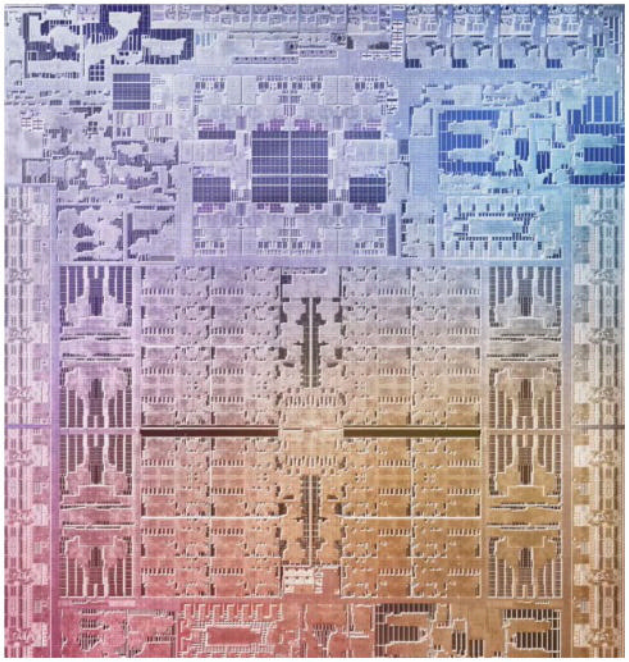
Obvious examples include DSPs or Digital Signal Processors, which can be used for tasks like decompressing media files, video encoders and decoders, encryption acceleration, and matrix math accelerators that are used for running AI algorithms.

What all of these heterogeneous blocks share is the ability to outperform a general purpose CPU at a specific task and by orders of magnitude. Alternatively, they can perform the same workload for a tiny fraction of the power consumption.

A great example is hardware video decode. Using the CPU cores to decode, say, a high bitrate H265 4K video stream will light up numerous CPU cores and suck up power. However, the same task on a hardware-accelerated decode block will mean the CPU cores barely register the workload, and the power consumption is only fractionally above idle power.

In that context, it really doesn't matter what instruction set the CPU cores run. The dedicated hardware is always going to be miles more efficient and powerful. The catch is that the more general purpose the computing device, the more you need general purpose compute cores. Arguably, smartphones are a good example of a device that relies less and less on the pure performance of CPU cores. The benefits to handheld devices of having dedicated hardware for running most common tasks is obvious enough for a portable device that has to rely on a relatively small battery.

On the other hand, for a desktop PC that might be required to do everything from gaming to media encoding, the benefit of plenty of traditional CPU power is equally obvious. A really powerful CPU, for instance, gives you the option of using new video codecs that might not be supported by existing acceleration hardware.



Apple's M1 and M2 chips are fully heterogeneous, with multiple special purpose blocks, as well as CPU cores.

arguably didn't even make the best use of the manufacturing resources it did have available when it came to smartphone SoCs.

By the time that final Broxton SoC was cancelled, it was widely being reported that Intel had blown $10 billion trying and failing to get into smartphones, and yet Intel probably hadn't actually spent enough. Throughout the period where Intel was attempting to break into the smartphone industry, it consistently prioritized its cutting-edge production technology and capacity for traditional PC processors, not smartphone SoCs. That's understandable up to a point—server, desktop, and laptop chips had long been where Intel made its real money.

But that attitude ensured that Atom was always later to Intel's newest production nodes than its Core and Xeon chips. As we've seen, with Intel's manufacturing technology beginning to slip, it didn't have any margin in hand. More specifically, Intel didn't invest fully to revise its existing manufacturing tech to suit the higher volume, lower cost characteristics needed to make smartphone chip manufacturing really competitive.

That would have meant refitting fabs that were optimized for larger, more expensive CPUs. Intel didn't do that, which meant that not only was it falling behind on process tech and delaying the roll out of Atom processors to the best nodes it had available, it was also using costly processes mainly designed for larger, higher-margin PC and server chips.

ARM-BASED CHIPS

All those factors together, and also considering the difficulty Intel was having just securing customers for its Atom smartphone chips, the whole Atom escapade looks doomed in hindsight. And yet, such is the importance of the smartphone today, it still seems like a massive opportunity missed and a huge strategic blunder. Again, if Arm processors do eventually replace x86 in servers and PCs, the failure of Intel's Atom project will almost certainly be seen as the key inflection point.

© APPLE CORP

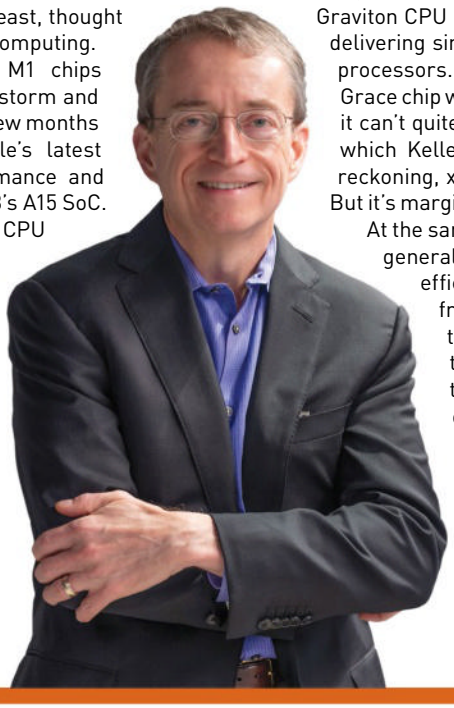
> Original Apple M1 chips contained the same high-performance Firestorm and high-efficiency Icestorm cores

Another reason why that's likely to be the case brings us to the key question of how Arm and x86 compare when it comes to performance and efficiency. Before Intel introduced the Atom, Arm chips were seen as comfortably more power efficient, with x86 clearly performing better.

Today, those historical assumptions are increasingly blurred. The most obvious examples are Apple's latest Arm-based chips. Apple's iPhones have been Arm-based since day one. However, it was the decision to begin transitioning all of its Mac computers from x86 Intel processors over to Apple's own in-house designed Arm-based CPUs starting in late 2020 with the MacBook Air M1 and Mac Mini M1 that proved Apple, at least, thought Arm was viable for true high-performance computing.

Funnily enough, those original Apple M1 chips contained the same high-performance Firestorm and high-efficiency Icestorm cores first seen a few months earlier in the iPhone 12. Similarly, Apple's latest M2 Mac chips use the Avalanche performance and Blizzard efficiency cores from the iPhone 13's A15 SoC. Remarkably, then, you get exactly the same CPU cores in everything from an iPhone to a full-tower Mac Pro, the latter being the last Apple Mac computer to make the move to Apple silicon in June this year.

Comparing performance metrics between Macs and PCs has never been simple. That was even true when Apple Macs ran essentially the same Intel chips as PCs. Now that it's x86 versus Arm, it's even harder to provide a level playing field. However, where the same application is available on and optimized for both platforms, at worst the cores in Apple's M1 and M2 chips are competitive with the next x86 processors.



Does Intel's IDM 2.0 strategy prove that CEO Pat Gelsinger knows the end is nigh for x86?

© INTEL

Indeed, by some measures, they can be much more powerful. Apple's M chips top out at a little over 3GHz, but can still be competitive with x86 processors running several GHz higher. Clearly, when it comes to IPC or instructions per clock, the M1 and M2 are often better than any x86 core from Intel or AMD.

Admittedly, other Arm-based cores aimed at consumers aren't quite as impressive as Apple's latest technology. Qualcomm's Snapdragon cores aren't quite as powerful, nor are the cores Arm licences to the likes of Samsung and others for its Exynos SoCs. But they're not that far off, and they're all much closer to full-fat x86 cores than would have seemed plausible 20 years ago. Seriously, if you'd suggested 20 years ago that half the world would have a phone in their pockets running multiple Arm cores, each with superior IPC to the best desktop x86 processors, that would have been awfully hard to believe.

A broader view of how cutting-edge x86 and Arm architectures compare came earlier this year from Jim Keller. Yes, the guy who headed up the design of the AMD Athlon 64 and AMD's Zen CPUs did a key stint at Apple as the company was ramping up the performance of its Arm chips, and more recently headed up CPU design at Intel, the fruits of which are beginning to emerge, but probably won't be fully clear until Intel's next-gen Arrow Lake and beyond CPUs appear in the 2024 to 2026 time frame.

GRAVITON

Anyway, Keller was doing a talk to university students in India, and posted a chart showing the comparative performance of a wide range of CPUs. Along with Intel's latest Xeon processor and a number of AMD x86 CPUs, including AMD's next-gen Zen 5 architecture, were several Arm-based CPUs. Keller's list had all three generations of Amazon's in-house Graviton Arm processors, plus Nvidia's Arm-based Grace CPU, for which the numbers were projected, but given Keller's provenance, if anyone can project the performance of an unreleased CPU with authority, it's him.

Now, according to Keller's figures, Amazon's first-gen Graviton CPU looks pretty weedy. But by Graviton 3, it's delivering similar performance to AMD Zen 1, 2 and 3 processors. Meanwhile, Keller forecasts that Nvidia's Grace chip will beat all existing AMD Zen CPUs, though it can't quite match the upcoming Zen 5 architecture, which Keller reckons will beat all comers. By this reckoning, x86 retains an outright performance lead. But it's marginal, something in the region of 15 percent.

At the same time, all of those Arm-based CPUs are generally thought to be significantly more power-efficient compared to the x86 alternatives from Intel and AMD. So, arguably the only thing that's preventing Arm from already taking over the server CPU market are the cost and engineering implications of supporting a new instruction set. But considering the ever-increasing cost of energy, if Arm continues to offer similar performance at much lower power consumption, it seems inevitable that companies will begin to shift over to Arm processors.

Another key indicator that the PC industry may be on the brink of a major

shift from x86 to Arm chips can be seen in Intel's self-professed future plans. Specifically, Intel's new strategy doesn't say anything explicitly about a move away from x86, but it does seem to tacitly acknowledge the future may not be x86, or at the very least, x86 will be less dominant in the general computing and server segments. Arguably, the most significant aspect of Intel's new triple-pronged IDM 2.0 strategy, announced in 2021, is the pursuit of customers for a new third party chip foundry service.

If you consider the other pillars in IDM 2.0, they don't really amount to much more than expediency and executing better. Point one is regaining leadership in chip production technology, which just means Intel doing its job better. The second pillar involves expanded use of third-party foundry services to manufacture Intel chips in the short to medium term, mainly at TSMC in Taiwan.

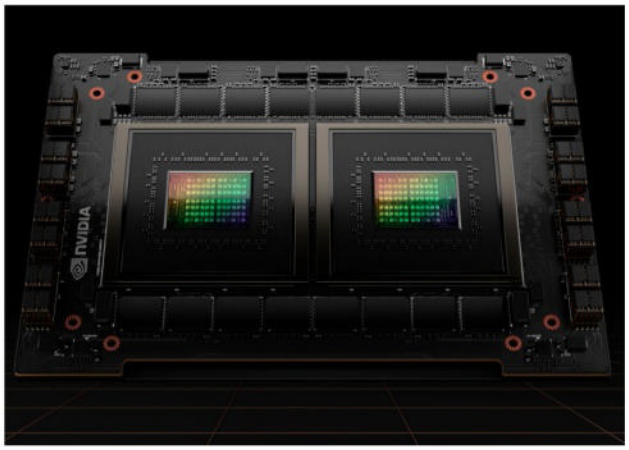
That's only necessary because of the failure of Intel's own fabs, and again, is hard to view as a major strategic move as opposed to an expedient measure that will be dropped just as soon as Intel's own fabs are once more competitive. So it's that third pillar comprising a new foundry business to make chips for customers that represents something novel. It really only makes sense in a world where Intel doesn't think x86 is king.

Instead, it's likely that Intel can see underlying instruction sets may matter less and less in future. That creates significant uncertainty for Intel's core business of server and PC chips. As things stand, Intel runs a duopoly in the x86 market with AMD and that means its customers are largely locked in. AMD is the only competition, and it doesn't even nearly have the capacity to step in and supply the entire market.

THE FUTURE

Intel can afford, on occasion, to release a less than stellar product. Up to a point, its customers just have to suck it up. But in a world where x86 versus Arm is less important than the overall performance proposition, including various heterogeneous compute elements, AI acceleration and other factors, Intel suddenly has to compete not just with AMD, but a whole slew of outfits selling processors, APUs, and SoC based on Arm, or even the RISC-V instruction set.

In that more meritocratic marketplace, continually being the best is an awfully big ask, so perhaps it's better for Intel not to even try. At the same time, the world seems to have an insatiable demand for advanced chip manufacturing capacity. While Intel has fallen behind TSMC, it along with Samsung makes up an unrivalled trio operating at the bleeding edge of chip production.



Nvidia is also getting in on the high-performance Arm server chip market with its new Grace CPU.

Moreover, the barriers to entry in terms of cost and expertise for any new player in the foundry business are now so massive, with the latest chip fabs costing tens of billions of dollars to build, that you can see how Intel could conclude that a foundry business is a safer bet than trying to cling on in the face of countless new competitors when it comes to chip design rather than chip manufacture. Indeed, new AI tools might mean that chip design becomes something of a commodity. It's harder for clever AI models to offset the complexity and cost of, say, installing and learning how to use one of ASML's $400 million warehouse-sized extreme ultraviolet lithography machines than it is to iterate a clever new CPU core design.

Of course, if Intel does see the writing on the wall for x86, it's hardly going to advertise that fact. Instead, you'd expect it to wheel out something like Intel IDM 2.0, laying the groundwork for its transition from a vertically integrated producer of specialized x86 processors to a third party chip foundry to rival TSMC.

In reality, Intel, like the rest of us, doesn't and can't know exactly what's going to happen. Maybe x86 will remain the dominant architecture in servers and PCs for many years to come. But at the very least, that looks dramatically less certain than it did 10 years or more ago. In the meantime, hedging its bets on a foundry business that could be very successful, whether or not x86 is eventually killed off by Arm, or indeed some other architecture looks like a very sensible hedge.

Apple's M1 and M2 chips have proven that Arm can compete with x86 for pure performance.

Arm is probably at more direct threat from RISC-V than x86.

As for what this means for our PCs? Probably nothing in the short term. It's unlikely that high-performance or gaming PCs will shift over to Arm chips in the next five to 10 years. But will a larger proportion of laptops run Arm chips in five years? Probably. If Arm begins to take over in servers, that will be the killer blow. Without the financial incentive the server market brings, the likes of Intel and AMD will have less reason to invest the resources to develop more advanced x86 CPU cores.

After all, the chips that go into Intel and AMD server CPUs may be different from those in our PCs, but the cores are identical, and there isn't enough money in client PCs to justify the kinds of engineering and development budgets that deliver radical new CPU core designs every few years. Where server CPUs go, our desktop and high-performance laptop chips will follow. All of this means that it may not be a nailed-on certainty that Arm replaces x86 in all of our PCs, but it is a pretty solid long-term bet.

> Of course, if Intel does see the writing on the wall for x86, it's hardly going to explicitly advertise that fact

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TAKING A BIG RISC-V

MAYBE THIS ISN'T ABOUT ARM VERSUS X86 AFTER ALL

Arm versus x86 is a battle for the ages, but is it already irrelevant? Is the real threat from another CPU instruction set altogether? Enter RISC-V, an open-source alternative to Arm, and many industry observers' pick for the long-term future of general purpose computing.

RISC-V's main benefit is that it's open-source. That means you can build a processor, or perhaps more pertinently a functional block inside an SoC without the need for a licence from Arm or buying in an entire x86-based chip from Intel or AMD. As its name implies, like Arm it's a Reduced Instruction Set Computer, so if anything, it poses a more direct threat to Arm than x86.

For now, RISC-V is mainly restricted to special purpose SoCs where the RISC-V cores are more enablers of the other dedicated functionality on the chip than the primary compute resource themselves. Indeed, most chips with RISC-V cores in fact run Arm cores as their primary general purpose compute.

In that market, it's not about a given core being 20 percent faster than the alternative. It's about freedom and the ability to innovate at speed without the need to conclude complex licensing arrangements. There are no limits to what you can do with a RISC-V core, where Arm licences dictate various stipulations and coherence with the Arm instruction set. What's more, companies using RISC-V don't have to release their core designs on an open-source basis, and likewise retain full IP rights and can freely sell their RISC-V-based wares.

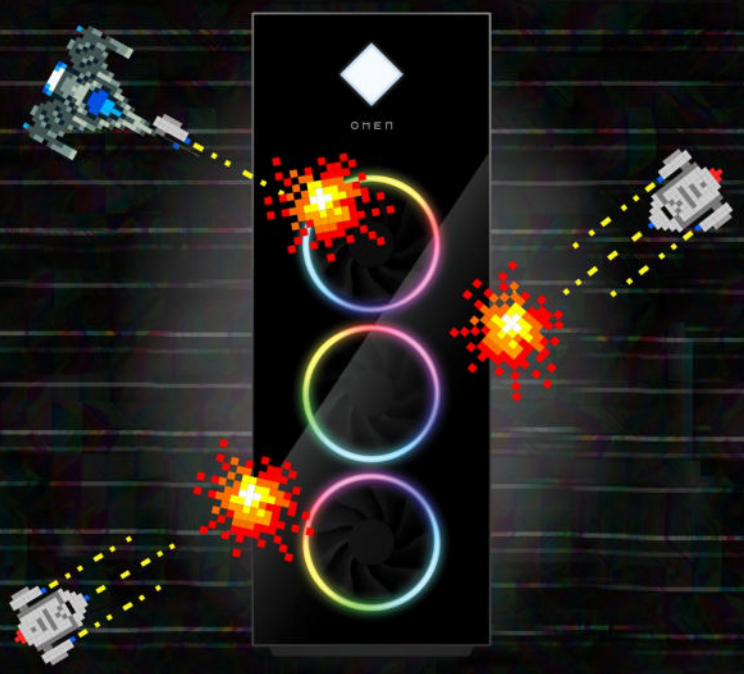
All that will probably apply to the broader compute market, eventually. In time, as heterogeneous compute becomes the norm, the character and performance of general purpose CPU cores will likely become commoditized. Most code may become platform or instruction set agnostic, at which point the idea of paying for an Arm licence or a premium for proprietary x86 technology won't make a lot of sense.

Of course, in the here and now, where code generally only runs well, or indeed at all on a specific CPU core instruction set, Arm and x86's great advantage is standardization, the guarantee of hardware and software compatibility within each given ecosystem. It's arguably inherent to the freedom and flexibility of RISC-V that compatibility isn't guaranteed, so RISC-V probably isn't a clear and present danger to Arm, let alone x86, which is a market that's all about reliability and compatibility. But in the really long term, RISC-V or something very like it taking over is ultimately inevitable.

GAME OVER

FOR GAMING PCs?

If you're looking for the ultimate gaming experience, does it still make sense to invest heavily in hardware? We look at the alternatives



HOLD ON! Before you splash out on a gaming PC, it's important to think about what you really need. Gamers have never had more options, be that traditional games consoles, Nintendo's Switch (and rivals), or cloud-gaming services.

This article isn't here to dissuade you from buying a $4,000 gaming PC, if that's what you want. But we would encourage you to think carefully and read about all your options before you jump in.

That's why we have analyzed what each sector has to offer. Whether it's Chromebooks, laptops, mini PCs, or towering desktop monsters, by the end you should know where to invest your money.

–STUART ANDREWS, BARRY COLLINS, TIM DANTON

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CLOUD GAMING

PLUSES

- Low cost of entry
- Older computers can be fine
- Works on Xbox

NEGATIVES

- Costs mount up
- PCs can be too old
- Fast broadband required

You can largely brush aside concerns about how gutsy your hardware is if you opt for cloud gaming. Largely, but not entirely.

The current pinnacle of cloud gaming performance comes from Nvidia GeForce Now's Ultimate tier. On that plan, you can stream games in 4K at 120fps on either PC or Mac, with the graphics settings maxed out on over 1,000 games, including *Cyberpunk 2077*, *Fortnite*, *Destiny 2*, *Rocket League*, and many more.

However, don't think you can run GeForce Now Ultimate on any computer. Although most of the heavy lifting is done by the RTX 4080 SuperPods in Nvidia's data centers, some local processing is required. On a Windows PC, you'll need a GPU that supports DirectX 11, a dual-core 64-bit processor running at 2GHz or faster, and 4GB of RAM. On Mac, Nvidia recommends a MacBook Pro from 2016 onwards, an iMac from 2017 onwards, or a MacBook Air or Mac mini from 2018 onwards. We've tried a 10-year-old iMac, and it didn't end well.

Your broadband connection needs to be up to it, too. For 3,840 x 2,160 or 3,456 x 2,160 streaming at 120fps, GeForce Now demands 45Mbits/sec. That's not a 45Mbits/sec connection; that's 45Mbits/sec of dedicated bandwidth for this application alone. At Full HD, GeForce Now can even crank up to 240fps, but that needs at least 35Mbits/sec.

Nvidia also recommends a wired Ethernet connection to keep things as smooth as possible, and we'd say that's a requirement if you want to avoid dropped frames and stutter warnings. Even using Wi-Fi 6 at close range, we've struggled to keep GeForce Now Ultimate streams as smooth as it is on Ethernet. If your device is not within wired reach of your router, that could be a problem.

The good news is that with a relatively modern computer, decent wired broadband, and a wired controller, gaming performance is strong. In *Fortnite*, with the graphics set to Epic settings on a 4K display, the frame rate rarely dipped below 120fps. In games such as *Cyberpunk*, you can have RTX switched on and lap up all of that ray-tracing loveliness. Crucially, latency stayed below 20ms, so you're not noticeably punished in online games.

GeForce Now Ultimate is expensive ($20 per month before games), and it does have particular hardware requirements. But it's the best gaming PC you've ever owned, without the hassle, noise, and upfront expense of actually buying one.

If you don't need the absolute apogee of gaming performance, then Microsoft's Xbox Cloud Gaming is worthy of consideration. Streaming tops out at 60fps at Full HD resolution on Microsoft's service, and you'll need to be a Game Pass Ultimate member to benefit from streaming.

Game Pass Ultimate covers both Xbox and PC games, but don't be fooled. Only Xbox games (and not even all of them) are available for streaming at the time of writing, although Microsoft has hinted that PC streaming is coming to the service.

As with GeForce Now, the service works more smoothly on Ethernet than Wi-Fi, even with the more limited resolution. Likewise, very old PCs might struggle to run the streams smoothly. Any half-decent laptop or PC bought in the past five or so years should be fine, though.

We frequently stream games on Xbox Cloud Gaming to a mid-range Android phone. It works best on phones with mobile-friendly games such as *Peggle 2*, *Coffee Talk*, or *As Dusk Falls*. GeForce Now also offers mobile apps, although it has fewer of these mobile-friendly titles in its library.

We've made frequent use of Xbox Cloud Gaming on PCs, Mac, and the Xbox Series X console. Even allowing for the reduced resolution, performance isn't as strong as it is with GeForce Now Ultimate, with latency occasionally an issue. But if you pick your games wisely, it still offers a very decent gaming experience. And, of course, the Game Pass Ultimate service provides the option to download and install games on the Xbox or PC locally, too.

GeForce Now Ultimate lets you stream games in 4K at 120fps.

© GEFORCE

CONSOLES

PLUSES
- Amazing value
- Slick gaming
- Great game selection

NEGATIVES
- No real upgrade option
- No keyboard or mouse
- Platform tie-ins

Some consoles allow you to play games wherever you are.

On one level, it makes zero sense to splash out on a gaming PC when today's consoles offer unbeatable performance at lower prices. Take the Xbox Series X. It has an 8-core, 16-thread Ryzen CPU running at up to 3.8GHz, plus a custom RDNA 2 GPU with 52 CUs running at 1.825GHz for approximately 12 teraFLOPs of number-crunching power. The nearest AMD desktop GPU—the RX 6750XT—runs faster, but would cost you north of $300 on its own, without the Xbox's CPU, 16GB of GDDR6 RAM, or 1TB SSD. Even if you could grab that stuff within the budget, you wouldn't have the cooling, the controller, or the case. The Xbox Series X is by far the best gaming PC you can buy for $499, even if it doesn't run Windows 11 in any form you know it.

True, Sony's PS5 doesn't have the same raw processing power, but it makes up for it with higher clock speeds and some ingenious power management. The Digital Edition without the 4K Blu-ray drive will set you back under $400. If you're happy with gaming at 1080p, the Xbox Series S gives you Full HD and sometimes 1440p gaming for under $300. You simply won't find anything comparable in the PC gaming space for that kind of money.

Maybe you prefer your gaming on the move. The hardware in Nintendo's switch is now ancient by gaming PC standards, yet *The Legend of Zelda: Tears of the Kingdom* remains one of the most visionary and critically acclaimed games of 2023. Even the premium OLED model with its stunning 7in screen could be yours for under $300. And while Valve's Steam Deck is effectively a handheld gaming PC, it's arguably better value than the big guys with prices starting at $360. You'll find yourself gaming in more places, more frequently, and you'll be amazed at how many blockbuster titles it can still run. The Asus ROG Ally has even more power, though that's reflected in the $699 price tag.

Unless you spend a small fortune on components, you won't be able to tell the difference between a game running on the Series X or PS5 from one running on a high-end gaming PC. What's more, console gaming just works. There's no fiddling with drivers or settings; games are tuned to run at a specific resolution at 60fps, or with higher settings at 30fps where there's a Quality mode. If a game glitches or performs badly, that's the developer's fault, not yours.

The PS5 Digital Edition will set you back under $400.

The other reason to get a console is that the hardware manufacturers invest heavily in exclusive games. Because these are designed to showcase the technology and drive gamers to their platform, these tend to be some of the most spectacular and satisfying games around. In recent years, the concept of exclusivity has changed. Microsoft has embraced PC gaming within the Xbox ecosystem, and releases its Xbox exclusives on day one on PC. Sony has started doing the same thing, but with a gap to make sure that if you want to play *Horizon Forbidden West* or *God of War Ragnarök*, you'll have an 18-month to two-year wait to do so on PC.

Finally, consoles offer an easy, subscription-based approach to playing games. Microsoft's Xbox Games Pass offers a huge and ever-growing library of recent and classic Xbox hits for a monthly fee, with its big exclusives appearing on day one. Sony's PS Plus Extra and Premium services do something similar, albeit with a longer six-month to one-year wait for the big exclusives to appear. You can enjoy Xbox Games Pass on a PC, and it's cheaper with an excellent selection of PC-only games. But why splash out on a hulking, RGB-lit desktop when a console will give you what you want, with no fuss, for less?

There are a couple of reasons. You can't upgrade a console beyond storage. This gives developers one fixed target for an eight-year cycle, and they can focus on wringing the best out of the machines, but it also means that by the end of that cycle, the hardware holds development back. Some late games on the last-gen PS4 and Xbox One struggled to do what they were meant to do on a dated spec. Even now, there are advanced games, such as *Starfield* or *A Plague Tale: Requiem*, that run at 30fps on console in their quality mode, but need a PC to run at 60fps with the same visuals.

Second, the console controller brings its own limitations. Complex RPGs and strategy games still thrive with a mouse and keyboard, where console controls and interfaces slow things down. There are also good reasons why most pro gamers still prefer a mouse and keyboard setup when accuracy and split-second timing count. There's an argument, then, that the PC delivers the ultimate gaming experience. But ask yourself this: is it really worth the cost?

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CHROMEBOOKS

PLUSES
- Cheap options
- Solid choice for cloud gaming
- Includes a keyboard

NEGATIVES
- Limited game options
- Limited performance
- Limited upgrades

You can largely brush aside concerns about how gutsy your hardware is if you opt for cloud gaming. Largely, but not entirely. Even when it had its own Stadia cloud gaming service, Google struggled to position Chromebooks as gaming devices. Perhaps that's unsurprising: with their low specs and lackluster screens, the average Chromebook was nobody's idea of a games machine.

Yet, Chromebooks have bucked up their gaming credentials. Mid-range and high-end Chromebooks have the screens and audio to make blockbuster games look and sound great. Chromebooks will work with those Stadia controllers, not to mention Xbox controllers and gaming mice.

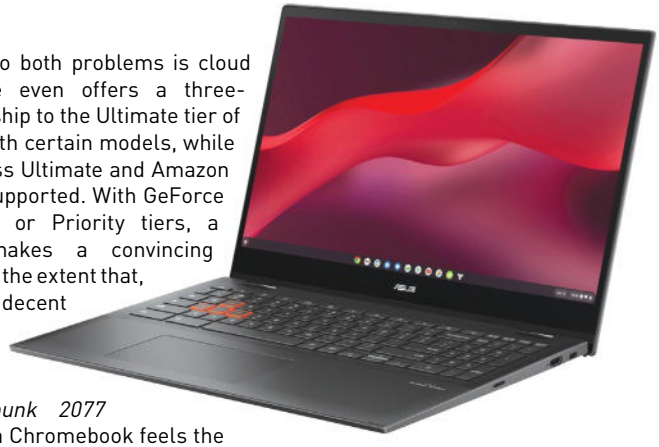
Acer, Asus, and Lenovo have even produced gaming-focused Chromebooks, complete with programmable RGB keyboards, 144Hz 16in QHD screens, Wi-Fi 6E networking, and improved specs.

Two big issues are compatibility and performance. While Valve and its Steam Deck have blazed a trail for Windows gaming on Linux, little of it has translated into the Chrome OS. As for performance, it's not hard to find a Chromebook with an Intel Core i5 CPU and 16GB of RAM, but it's impossible to find one with a dedicated GPU.

The answer to both problems is cloud gaming. Google even offers a three-month membership to the Ultimate tier of GeForce Now with certain models, while Xbox Games Pass Ultimate and Amazon Luna are also supported. With GeForce Now's Ultimate or Priority tiers, a Chromebook makes a convincing gaming laptop to the extent that, if you have a decent fiber connection and don't notice the input lag, playing *Cyberpunk 2077* or *Destiny 2* on a Chromebook feels the same as on a Windows gaming laptop.

Chromebooks also have another strength—a standard mouse and keyboard interface. You can still use a controller for action games, shooters, and racers, but you have the option of switching back to mouse and keyboard. This actually makes a Chromebook a great companion device for, say, a Steam Deck or a console if you're happy to stream games through GeForce Now.

Meanwhile, native Steam gaming is coming to Chromebooks. The recommended games list is depressingly short, partly thanks to the lack of GPU hardware. Yet the list is growing, and there's evidence that upcoming Chrome OS development boards may pack Nvidia GPUs for the first time. Gaming Chromebooks with dedicated GPUs running Windows titles through Steam and the same Proton layer used by the Steam Deck could be a very enticing prospect.



The Asus Chromebook Vibe is designed for gaming.

Microsoft's Surface Laptop will play undemanding games, but it has plenty of limitations.

NON-GAMING LAPTOPS

PLUSES
- Capable in undemanding games
- Affordable choices

NEGATIVES
- Demanding games unplayable
- Very limited expansion

You may be surprised at how capable modern Windows laptops are when it comes to gaming. Intel's Iris Xe graphics can run *Counter-Strike: GO* and *GTA V* at rates well above the 60Hz refresh of their typical screens, and there's enough power to run *PUBG* and *Fortnite* if you dial down the settings. The same is true for any modern AMD-powered laptop with Radeon graphics.

However, just because a laptop includes a Core i3, i5, or i7 processor, it doesn't mean it will produce playable frame rates in *CS: GO*. One particular quirk is that Iris Xe requires two sticks of RAM; if you only have one SODIMM, or embedded onto the motherboard, then it's plain old Intel UHD Graphics. The silicon is the same, but in our experience it means that games play at around 70 percent of the speed.

This brings us to another problem with non-gaming Windows laptops: expansion. You'll be stuck with the graphics built into the processor, for a start—the only exception being if your laptop includes a Thunderbolt 4 port. In that case, you can upgrade your graphics via an external graphics case. AKiTio, Cooler Master, and Razer all make them, but they're expensive options at around $300.

That's not the only pressure point. While many Windows laptops offer a way to upgrade internal storage, few will go to this trouble—and you may find that the supplied 256GB or 512GB SSD is rapidly filled after installing a game or three. External storage is workable, but clumsy and, unless you have a fast interface (USB 3.2 Gen 2 at 10Gbits/sec as a minimum), you may find it annoyingly slow.

If your needs are undemanding, then you should be happy with a non-gaming Windows laptop. But if you want to play the latest games, you need to upgrade to a proper gaming machine or give cloud gaming a go.

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GAMING LAPTOPS

PLUSES
- Superb, fast screens
- Slim, stylish options
- Can be surprisingly cheap

NEGATIVES
- Limited power vs desktops
- Usually beefy machines
- Expensive at cutting edge

Gaming laptops come in many sizes, but there is one simple rule: the bigger they are, the more powerful a card can be squeezed into the chassis, and the faster your laptop will be. And they can be chunky, often weighing over 2kg.

Unlike gaming PCs, there will be a limit on the power a chassis can contain: the current generation of mobile GeForce RTX cards peak at 175W compared to the 450W of the desktop RTX 4090. The Asus ROG Strix Scar 18 is one of the most powerful gaming laptops in the world, and in its RTX 4090 incarnation it averaged 86fps in *Metro Exodus Enhanced Edition* at 1600p (its native resolution) and Extreme settings. The HP Omen 40L with the desktop card scored 120fps at 1440p and 75fps at 4K. Alternatively, compare their 3DMark Time Spy Extreme scores: 9,513 for the laptop, 17,322 for the desktop.

However, there's an element of "so what?" about this. Despite many gaming laptops now including lush OLED screens with 240Hz refresh rates, there's only so much competitive edge and smoothness a frame rate of above 60fps can give you. Sure, people who play multiplayer games competitively will benefit, but most will struggle to spot the difference between 60fps and 120fps when gaming.

The other issue is expense. High-end gaming laptops don't come cheap, with the top-end ROG Strix Scar 18 costing $3,699. With a gaming laptop, there's sometimes the option to add an extra M.2 SSD and perhaps to replace the memory, but that's it.

Still, don't write gaming laptops off. You can buy inexpensive options with last year's graphic cards, such as the MSI Prestige 15. This includes an RTX 3050, and averaged 59fps in *Shadow of the Tomb Raider* at 1080p and High settings.

There's another way of looking at gaming laptops. Buy a sleek machine, such as a Razer Blade or Asus ROG Zephyrus, and you're buying a highly portable productivity machine that transforms into a gaming system on demand.

A gaming laptop will provide playable frame rates, but at a price.

GAMING PCS

PLUSES
- Easy to upgrade
- No upper limit to speed
- 100% compatible

NEGATIVES
- Big upfront investment
- Power hungry
- Can be noisy

Although this feature celebrates the many forms of gaming PCs available now, there remains one clear choice if you need the last word in performance: a true gaming PC. Think chunky chassis with space inside for the latest graphics cards, with cards based on Nvidia's GeForce RTX 4090 typically measuring over a foot long.

Few people will benefit enough from such a card to make it worth the $1,500 investment (and that's for a basic, non-overclocked version). You can get smooth frame rates at 4K of above 60fps in even challenging games such as *Cyberpunk 2077* with much lesser cards. And if you're happy with 1080p or 1440p and less demanding games, then a mid-ranger such as the new GeForce RTX 4060 will do you proud.

Which card should you choose? One of the benefits of a gaming PC is that you can keep one eye on the future. If you only intend to play games on a 1080p monitor for the next year or two then you would be wasting your money on one of Nvidia's or AMD's latest-generation cards. Hunt on second-hand auction sites, and you can pick up a still-speedy RTX 2060 card for under $100, or buy one of the low-end cards from AMD or Nvidia based on the previous-generation technology.

Doing so means you can concentrate your budget on the processor and motherboard at the start, as both components are tricky to upgrade. Nor do they date as quickly from a gaming point of view.

The other fantastic thing about gaming PCs is down to the modular design introduced by IBM way back in 1981. A great gaming chassis from a decade ago remains a great gaming chassis today; and likewise, looking ten years into the future. Invest wisely, and you'll be able to swap out components as you go through its lifetime while still enjoying the external design you decided on.

Make no mistake, custom gaming PCs can make a statement in a way that laptops never will, no matter how many decals you slap on them. With space for sophisticated addressable RGB setups and an almost infinite number of chassis, what you build or buy will quickly become your own.

It's this level of customizability that gives gaming PCs one element that nothing else here can: this is your personal system. That doesn't mean you have to build it and support it yourself. We're fortunate in the UK to have numerous specialist PC makers who will take the risk out of builds by doing it for you, often at prices that you'll struggle to match if you buy components off the shelf. Names like Chillblast, CyberPower, PCSpecialist, and Scan are all extremely experienced in taking a dream spec and turning it into a tested, functioning PC.

Or perhaps you prefer to buy an "off-the-shelf" gaming PC, where the parts

Light fantastic: a true gaming PC offers many advantages

MINI PCS

PLUSES
- Compact chassis
- Energy efficient
- Usually affordable

NEGATIVES
- Struggle with top-end titles
- Can be underpowered
- Limited upgrades

The NUC-sized mini PC might not be the first thing you think of when mentally speccing out a gaming PC, but don't write them off too quickly. These compact devices won't have enough space to accommodate a desktop graphics card, but the power now available from even integrated mobile graphics means you can get a decent level of gaming performance.

Take the Geekom AS 6. This compact box is small enough to fit on a monitor stand or even attach to the back of a screen with the supplied VESA mount. Yet it's powerful enough to play some modern games at 4K.

The AS 6 is well specced for a device of this type. It contains an AMD Ryzen 9 6900HX processor, capable of bursting at up to 4.9GHz. That has Radeon 680M graphics, which is a chip with 12 graphics cores, and which AMD claims will outperform entry-level dedicated mobile GPUs. In the AS 6, it's complemented by 32GB of DDR5-4800 RAM and a 1TB M.2 SSD, which helps keep things nimble.

Even at 4K resolution and with graphics on high quality, it can play *Fortnite* at around 40fps. There was certainly the odd stutter, it's not exactly smooth when chaos erupts, and there are bullets flying everywhere, but it is playable. Dropping to Full HD resolution pushes the frame rate to 60fps+, which gives you a fighting chance.

It's a similar story in *Rocket League*. The action judders a little at 4K high quality settings, once again delivering an average of around 40fps. Dropping to "performance" graphics settings increases the frame rate to a smoother 50fps, while climbing down to Full HD with performance settings delivers a smooth road ahead at 60fps+.

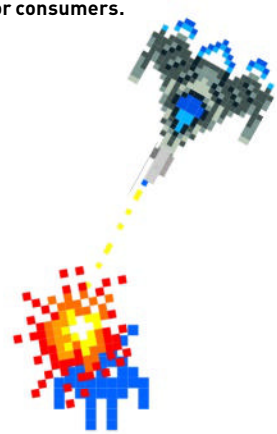
Top-end titles such as *Cyberpunk* are a stretch for this box of tricks, but more sedate games, such as *Death Stranding* and *Cities: Skyline*, run smoothly, even at 4K. In short, if you're not bothered about the bleeding edge of gaming, and can live with playing games at Full HD, a compact PC such as the Geekom AS 6 holds an unexpected level of appeal. Even when it's being pushed hard, the total system power consumption barely peaks above 80W. Fan noise isn't a big problem, either.

It must be said that the Geekom AS 6 is well specced for a mini PC, particularly at $659. You won't get this level of gaming performance from these NUC-style boxes, so pore over the specs if you're considering rivals.

The best known mini PC of all is, of course, Apple's Mac mini. Gaming on the Mac is hard to compare directly with Windows because of the lack of crossover titles, but there's no reason why you can't expect to do some modest gaming.

The base Mac mini has a 10-core GPU, although the 256GB of storage and 8GB of unified memory could prove bigger barriers. The top-end model comes with a 16-core GPU and 16GB of memory. Our colleagues at Tom's Guide tested an M2 Pro configuration with a 12-core GPU and 16GB of RAM, benchmarking *Rise of the Tomb Raider* at 53fps at 1080p. *Sid Meier's Civilization VI: Gathering Storm* graphical benchmark hit 50fps at 1080p and 44fps at 4K. These aren't bleeding-edge titles, but the Mac mini delivers better gaming performance than many might expect.

The Intel NUC 9 Extreme Kit is the highest performing Intel NUC available for consumers.



The tiny Geekom AS 6 can play some modern games at 4K.

have been chosen by companies. Not just the likes of Acer, Alienware, HP, and Lenovo—who all offer their own chassis designs that may appeal to your aesthetic—but again, the British manufacturers.

The international brands have become better at building gaming PCs with expansion in mind, but you must still do your research. The best way to add storage is via M.2 slots, and you won't be able to go into detail about motherboard layouts, which version of PCI Express is supported, and how many 2.5in SSD drives are available, as you will if you know which motherboard and chassis you're buying.

Of course, some people may see this level of research as a downside of a gaming PC (weirdos). It's true that there are more variables with a gaming system, with decisions you make at the point of purchase echoing through the years. Then there's the sheer bulk of the things, their greed when it comes to power consumption, and the amount you have to pay for a high-quality system.

But if you really love gaming, nothing will match the experience of a well-built gaming PC. We may have called this feature "Game over", but as ardent gamers will know, the fun has only just begun.

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GREEN PCs MISSION IMPOSSIBLE?

The world's biggest PC maker says it can achieve net-zero by 2050. *Barry Collins* visits Lenovo's US headquarters to get his hands on plant-based PCs, bamboo packaging, and vegan leather covers

IT'S NOT EASY being green, as a wise young frog once sang. It's definitely not easy if you're a global PC manufacturer in an industry where the trend has emphatically swung towards sealed, largely unrepairable devices over the past decade.

How far can a company such as Lenovo swing the pendulum back in the other direction? That's what I was invited to the company's US headquarters in Raleigh, North Carolina to find out. (No, the irony of flying thousands of miles to find out how a company plans to become much greener wasn't lost on any of the participants.)

There, I saw how Lenovo was making greater use of recycled materials, laptop cases from flax, packaging from bamboo, computers that are designed to last longer—and servers that are cooled with water instead of energy-hungry air conditioning. They're all part of Lenovo's goal to become net-zero by 2050, with some stiff targets to meet in the much shorter term, too.

Can a top-tier PC maker shifting tens of millions of PCs every year really make zero contribution to global greenhouse gas emissions within 30 years? Nobody can know for sure, but there's zero doubt that the company is at least taking steps in the right direction. Let's explore what they are.

RECYCLED PC CASES

Lenovo sells a lot of PCs—almost 69 million of them in 2022, according to research firm Gartner, making it the biggest box-shifter in the world by quite a margin. It accounts for just under a quarter of global PC

Lenovo's headquarters in Raleigh, North Carolina

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shipments, so can have a sizeable impact on the Earth's resources if it can make better use of recycled materials and create less waste. Not least because, as market leader, it can set an example for other manufacturers to follow.

There's upward pressure on the company to do less damage to the environment, too. "Every customer I speak to says, 'Do you have a target for driving zero carbon emissions?'" says Tom Butler, the company's executive director of commercial portfolio and product management (Lenovo could make serious environmental savings on business card printing by cutting the length of its job titles).

One of the ways in which Lenovo is reducing waste is with the increased use of natural or recycled materials for PC and laptop cases. We're taken up to Lenovo's design lab, where we're surrounded by laptop case designs, stretching back to the beige IBM-branded primitive laptops of the 1980s, right through to prototypes of unreleased devices that are annoyingly hidden beneath a thick black sheet.

Also in the lab are prototypes of various materials that Lenovo is developing for its forthcoming laptop ranges. There are samples of "vegan leather", made from cactus, that could be used for laptops or cases. There's carbon fiber, reclaimed from the fuselage of Boeing airplane bodies before being forged into plates that each have a unique pattern, giving them an interesting design aesthetic. And there are laptop lids for the ThinkPad Z13 Gen 2, which are made from harvested flax plant fibers. They're woven together with tree sap and, again, each has a unique texture due to those woven flax fibers.

Butler wants to demonstrate that the flax covers are no less durable than their plastic or metal equivalents, and does so by dropping the laptop from waist height and then standing on it. "Now, turn it on," shouts one of the journalists in the room, and there's an awkward moment where he presses the power button and nothing appears on the screen. He hands the ThinkPad to a colleague who, having not left the room with the eyes of a dozen journalists fixed on him, brings the working laptop back to Butler a minute or two later. "Unexpected Windows update," the colleague explains.

Vegan leather and flax covers are all well and good, but the majority of the range will still be made from plastic or metal for the foreseeable future. Here, the company claims to be making good use of recycled materials. Every laptop in the ThinkPad range contains some Post-Consumer Content [PCC] materials. For example, the covers used for the top and bottom covers on some ThinkPads use 75 percent recycled aluminum.

Why not 100 percent recycled materials across the board? "As you use recycled material, it loses some of its strength and durability properties," Butler explains, potentially harming the lifespan of the laptop, which would be counterproductive. "Plastic PCC breaks down—I can use it for five generations, and then it degrades."

The firm tests recycled material to find out how many generations of recycling it's been through—the properties of the plastic change with every generation of reuse. However, new life can be breathed into old plastic by mixing it with fresh materials. "We have to use a blend of recycled content, as well as some new content," says Butler. "That's why you don't see 100 percent recycled content."

PLASTIC-FREE PACKAGING

It's not only the computers themselves that potentially create plastic waste, but the packaging, too, although not for much longer. All ThinkPad packaging will be 100 percent plastic-free by the end of the year, according to Butler. "Even down to the security label that goes over the package," Butler adds.

Up in the design lab, we're shown how Styrofoam packaging designed to protect the laptop from shocks and bumps in transit has been replaced by bamboo inserts. Why bamboo? It grows quickly, requires relatively little water, and is compostable. To prove it, Butler holds up a bamboo packaging insert that he laid on the soil in his own garden a year ago. I say holds up—what's left of the bamboo is in a clear plastic folder, because it has largely disintegrated.

ThinkPad packaging will be 100 percent plastic-free by the end of 2023.

Lenovo's commitment to environmentally friendly materials stretches to the ink used to print the company's logos, where it's experimenting with algae-based ink. The problem with the algae inks? They're struggling to find a pigment that matches the trademark IBM/Lenovo red you see on the keyboard TrackPoint.

Bamboo has replaced Styrofoam for packaging, as it's biodegradable.

MAKING PCS LAST LONGER

Lenovo's laptops already have a strong reputation for durability, even in my household. A ThinkPad that fell out of my rucksack and skidded across a street remains in active use as my daughter's day-to-day laptop five years later. However, the company admits it's got more to do to make its products longer lasting.

From the moment Steve Jobs slid the very first MacBook Air out of a manilla envelope, the laptop industry has been obsessed with slender, sealed

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units that are often difficult, if not impossible, for professionals to repair, let alone individuals. "The primary constraint is what the market demands in terms of form factors and functionality, weight, battery life, all those sorts of things," admits Lenovo's senior technologist, Kevin Beck, when I push him on why laptops in general have become less repairable over the past decade or so.

But he pushes back on areas where Lenovo has resisted some of the industry's least environmentally friendly practices. "We do not use any soldered-on SSDs," he says, at least in the company's business-orientated products. "That is primarily because there are a large number of different regulations and company policies around data retention. If they have personally identifiable customer or patient data on it, they can't allow that data, even if encrypted, to leave their premises. So when they have to send something off to be repaired or replaced, they want to be able to take that [SSD] out."

Likewise, Beck insists that components such as screens aren't glued down. "There has been adhesive tape," he concedes, "but they were removable and were included in the repair kit for the technicians," although you couldn't necessarily buy that tape on the open market.

What about soldering down RAM? "Soldering of RAM is driven primarily by form-factor concerns," Beck responds. "Some of it is onboard and part of the motherboard, but the connectors are industry standard, and are of a certain thickness. We can't go off, and nor do we want to go off, and design some brand new, proprietary memory interface. That is a constraint, but I know we are looking at ways of making it better."

Modular laptops are popular with customers, but barriers persist.

Beck insists that repairability remains a key priority for the company. Indeed, by 2025, Lenovo set a very specific target that 84 percent of PC repairs should be eligible for on-site customer service rather than having to be shipped back to a depot, with all the inconvenience, cost, and transport emissions that creates.

To that end, the company makes the hardware maintenance manual of every ThinkPad available online—it has done since day one—and produces YouTube videos to help customers repair or upgrade its machines themselves. ThinkPads only use standard screws and tools, so there's no artificial barrier. He gives an example of how the company evolves products to make them more repairable. For example, the first foldable ThinkPad, the X1 Fold, "did not pass our own criteria for onsite repair. It was repairable to an extent, but it had to be sent back to us." For the second generation, the company changed the cover design, made it detachable by removing a screw, and then popping a thin screwdriver into a hole on the side of the case to pop it off.

The company has also been doing work on the beep codes that indicate a serious hardware fault. Instead of relying on customers to work out whether it was, for example, one long and two short beeps or three short beeps when diagnosing faults, the company created a smartphone app so customers could place their phone by a faulty PC and have it diagnose the problem by listening for beeps. However, the company soon realized that asking already harassed customers to download a separate app was making a bad situation worse, so now customers are asked to hold their phone near the faulty laptop when talking to a service center, with the phone system able to do the same job the app did.

Developing these things comes at a cost, but as Beck explains: "When we look at how much it costs to make a product, we look at the lifespan, including the warranty. There are places where we've decided to spend a few cents up front... to make it cost-neutral, to reduce the amount we spend to repair it over the course of its life."

MAKING MODULAR LAPTOPS

Up in the labs, one of the ideas Lenovo is kicking around is making laptops more modular. Granted, this is hardly radical thinking. Framework has garnered a lot of attention and praise for its modular laptops, which provide toolless access to the internals, letting you easily replace or upgrade components such as the battery, storage, or keyboard.

Lenovo knows the concept is attractive to consumers. It shares the results of a survey with us, which polled 2,000 consumers in various geographies. Just under three quarters felt repairability was very important, 59 percent wanted devices to be repairable by the manufacturer, and 22 percent wanted to be able to perform repairs themselves.

Kevin Beck says Lenovo is not about to take the exact same approach as Framework, but it is interested in the idea. "The concept of modularity is something we're actively looking at and exploring," he says, although he quickly caveats that with some of the difficulties of shipping laptops with replaceable parts.

Lenovo is reducing waste by using recycled materials in cases.

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He says that if you mapped all the interconnections between different components and assemblies, "it would look like a galaxy between all the considerations of the parts, the lifecycle, the stocking costs, moving it around the world, the minimum order quantities for certain things. It just has to be balanced."

Then there's the fact that Lenovo can't do this alone—it needs component manufacturers to get behind the idea of modularity. "It is definitely something that the entire industry is going to have to row in the same direction on, to some extent," he adds.

Beck senses my doubt that Lenovo is ever going to get round to delivering a modular laptop with so many barriers being put in its path, but he ends on a more confident note. "It's hard to see the end of the road because it's so complex to know where we'll end up," he says. "I'm not equivocating, for that reason. It could go so many ways, but the upside of that is there's a lot of talk, there's a lot of possibilities."

RECYCLING COMPONENTS

A lot of the focus so far has been on creating new products. But finding better ways to deal with old equipment is also high on Lenovo's priority list, not least because its environmental targets stretch up to the supply chain and down to what customers are doing with Lenovo equipment.

Lenovo provides several examples of how materials reclaimed from old equipment are reused, including in high-end jewelry. But there are only so many people who want a ring made out of old motherboards, so Lenovo is putting effort into reusing components that haven't reached the end of their useful lives. "A stated part of the strategy that we're adopting around the circular economy is to find ways to reuse parts from old systems in the right way, or to extract value from them in some other way," says Beck.

Beck insists old components won't be reused in "new" PCs, but components or whole systems can be harvested and resold as used equipment. Around 60 percent of the PCs brought in through the company's corporate asset recovery programme are reused, an executive claims in a presentation. However, Beck says the company is also making efforts to reuse perfectly good returned parts.

"There's a surprising amount of what we call NDFs—no defect found," says Beck. "The customer thought it went wrong, it didn't work for some reason, but when they get it back in, the brand new part [was fine]. So that's what we mean by parts reutilization in the active servicing programme, and that is something that we have metrics on for all of our business partners and authorized servicers. It's the degree to which they're doing the right thing with the parts."

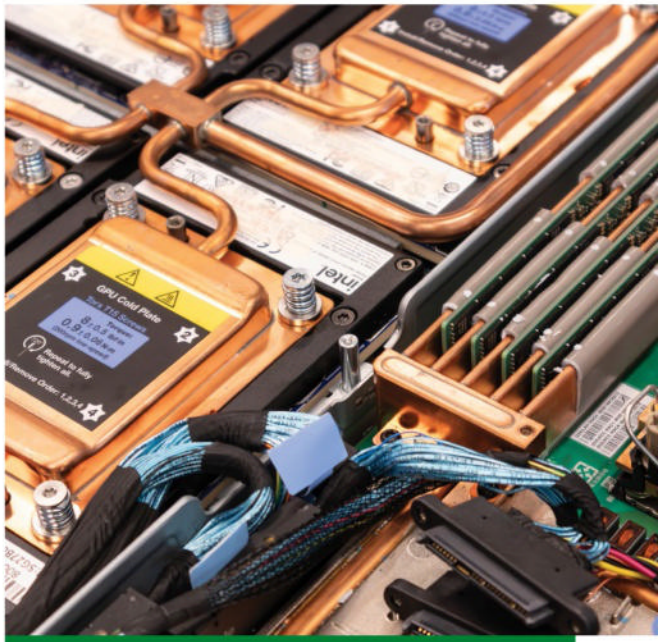
MEETING THE CHALLENGE

We're in an industry with too much greenwashing. Too many spurious claims of environmental benefits, too many companies where the green commitments extend little further than the press release. Part of the reason I accepted Lenovo's invite to Raleigh was to see if that was the case here.

It clearly wasn't. Of course, we were only shown what the company wanted us to see, and I've no doubt that Lenovo's commitment to profitability trumps its commitment to the environment. It's a successful business, not a charity. But what I saw was strong evidence of a company trying to do the right thing, with executives who seemed enthused at the idea of making the business less resource-hungry, less wasteful. Not least because it's often as good for the bottom line as it is for the environment.

It's doubtful whether any of the executives I spoke to in Raleigh will be there in 30 years' time to be held to account for those net-zero targets. Most of them had as many gray hairs as me. But if they manage to imbue the same enthusiasm and dedication into the next generation of managers, there's a fighting chance those targets will be met.

Lenovo is now making laptop cases from flax.



SERVERS THAT HEAT A SWIMMING POOL

There are few things more power hungry than data centers, and their power consumption is set to quadruple by 2030, according to Lenovo.

More than 30 percent of a regular server's energy is devoted to the cooling fans, which is why Lenovo is continuing to develop its Neptune water-cooling technology—a far more energy-efficient way of keeping servers from cooking.

There are two types of water-cooled server in Lenovo's lineup. There are fixed-loop systems, where the same water is cycled around the server and passed through a radiator, cooling the server much like a liquid-cooled PC. Then there are open systems, where the water is pumped around the entire rack, where cold water enters the system and warm water comes out.

It's what happens to that expelled warm water that's helping to keep the system more energy efficient. In some instances, it's being used to heat facilities, or provide warm running water for taps and showers. One company is currently experimenting with using the hot water from its server stack to heat a swimming pool, according to Patrick Moakley, director of marketing for HPC and AI at Lenovo.

Water-cooled servers come with some drawbacks. They are typically around 10 percent more expensive than fan-cooled systems, according to Moakley, though he claims companies will recoup that upfront investment with savings on their energy bills within 12-18 months. The water cooling is often more effective than fans, too, meaning processors can be clocked to higher speeds. Both Intel and AMD now have water-cooled-only SKUs, according to Moakley, because fans aren't capable of keeping the chips cool enough.

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HOW TO

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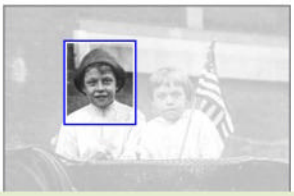
TIP OF THE MONTH

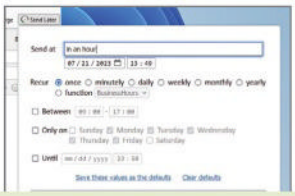
COLOR HUNT

If you're a creative person—whether commercially or as a hobbyist—then Color Hunt is a great place to find color swatches for your designs. On the colorhunt.co website, you'll see a nearly endless selection of swatches, with categories and themes along the left-hand side. Each swatch has the exact hex code, which you can copy and paste straight into your design application. Pretty handy, hey?

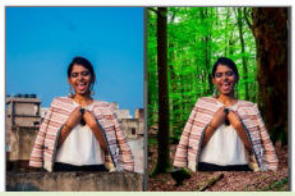
MAKE – USE – CREATE



62
Record your family history with Gramps



66
Master three great Thunderbird add-ons



70
How to use Generative Fill in Photoshop

SAM LEWIS
STAFF WRITER

A HELPING HAND FROM AI

To put it bluntly, AI scares me, but it has its perks. I've used it for design work with Adobe Photoshop's generative fill tool, and to boost my gaming experience thanks to DLSS 3.0. This is the best way to improve a 40 series Nvidia GeForce graphics card, and when testing the RTX 4060, it proved that you don't have to spend the big bucks to get a premium experience. Sure, there are plenty of reasons why a more expensive and premium graphics card is worth it, but it's impressive to see what we can get out of the lesser-powered models.

Nvidia's DLSS technology has been around for over five years, and is improving. The latest 3.5 version (soon to be released at the time of writing) improves frame generation, raytracing has a newer AI model, and brings in rayreconstruction. Titles that are supported, such as *Cyberpunk 2077*, can take full advantage of this AI tech, which is exciting, considering how much I already enjoy running it with DLSS 3.0. I'm currently running it on an RTX 4060 at over 100fps on a QHD display. To me, this already looks stunning, so I can't wait to advance things further. On the flipside, it will turn me into an office gremlin, so I'll have to take some tactical trips outdoors, otherwise I'll be missing out on Vitamin D!

↘ submit your How To project idea to: editor@maximumpc.com

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Record your family history with Gramps

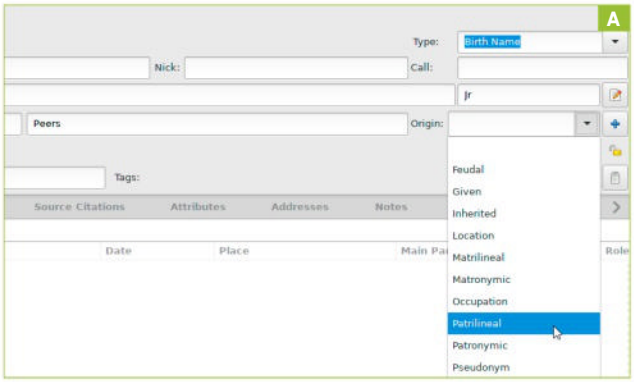
YOU'LL NEED THIS

GRAMPS
A free open-source tool (https://gramps-project.org), plus access to your family tree, photos, and any research notes (including documentary evidence).

HOW WELL DO YOU KNOW your family history? What interesting stories are hidden away? There's never a bad time to start digging, and once you've mined family members for their own tales and memories about your forebears, you can embark on a more rigorous search for information using the rich online resources at your disposal from the likes of Ancestry and MyHeritage.

The question remains, however, as to how you bring all this research together in a single place for easy recording, retrieval, and sharing with others. You'll find plenty of paid-for options, such as Family Tree Maker and RootsMagic, but why spend money when Gramps is free, open-source, and contains all the tools you need to not just record the dry facts, but also inject some color into your ancestors with the help of space for stories, your family photos collection, and the ability to pinpoint key locations from your family's past on a map?

Gramps can be a little overwhelming when you first launch it, but this tutorial will help you navigate the program to bring all the salient facts, stories, and photos that make up your family's history under one roof. –NICK PEERS



1 GET STARTED

Head over to https://gramps-project.org/blog/download/ and click the 'Download Gramps' link to access links for all supported platforms, including both installer and portable versions for Windows. In most cases you'll be installing the 64-bit version, so download that and double-click it to launch the installer.

» During setup, click Run anyway if the Smartscreen filter pops up, and when prompted to select components during the setup process, expand Dictionaries to ensure en-US is checked before clicking Next. Once installation completes, click Finish and wait for Gramps to launch.

» Three windows will open (one of which should quickly close). Make sure the Family Trees—Gramps window is in the foreground, and click New to create your tree. Rename it as required, and double-click it to open it in the Dashboard window, which you'll likely need to resize before continuing.

2 INSERT FIRST PERSON

You'll find yourself at the main Gramps dashboard, which is basically a multi-paned window that can be customized (see the annotation for details). Let's start by building your tree. Gramps showcases the basic structure employed by most family history programs: you create individuals (People), then link them (Relationships) to their immediate relatives as part of parent/children groups (Families).

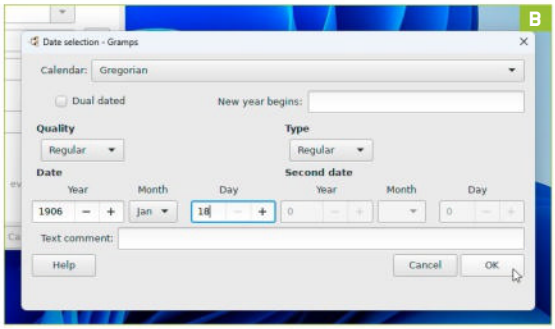
» Step one is to create the first member of your tree, which is typically yourself. First, select People from the left-hand pane to switch to a new view. Click the blue + button in the toolbar to enter your details in the Person window. Start by entering your forename(s) into the Given field, then your birth surname into the field to the right of the field marked prefix.

» Other fields are optional—for example, 'suffix' is where you add 'Jr' or 'III' if relevant, while Origin can be used to record where your surname originated—typically 'Patrilineal' if you took your father's surname. The Gender dropdown is self-explanatory, but only supports male or female, so leave as unknown if you're non-binary (an 'Other' option is slated to appear in version 5.2). Once you've filled in as much (or as little) detail as you need [Image A], click OK to proceed.

3 ADD YOUR FIRST EVENT

You'll see your surname appear on the main screen: click it to expand it and reveal your personal entry. Double-click this to return to the Person Editor screen and add some flesh to your genealogical bones.

» Start by adding your married name if applicable: select the Names tab, then click the + button beneath it to open a new window (Name Editor). Set the Type dropdown to 'Married Name', and fill in the details as before. Click OK when done.



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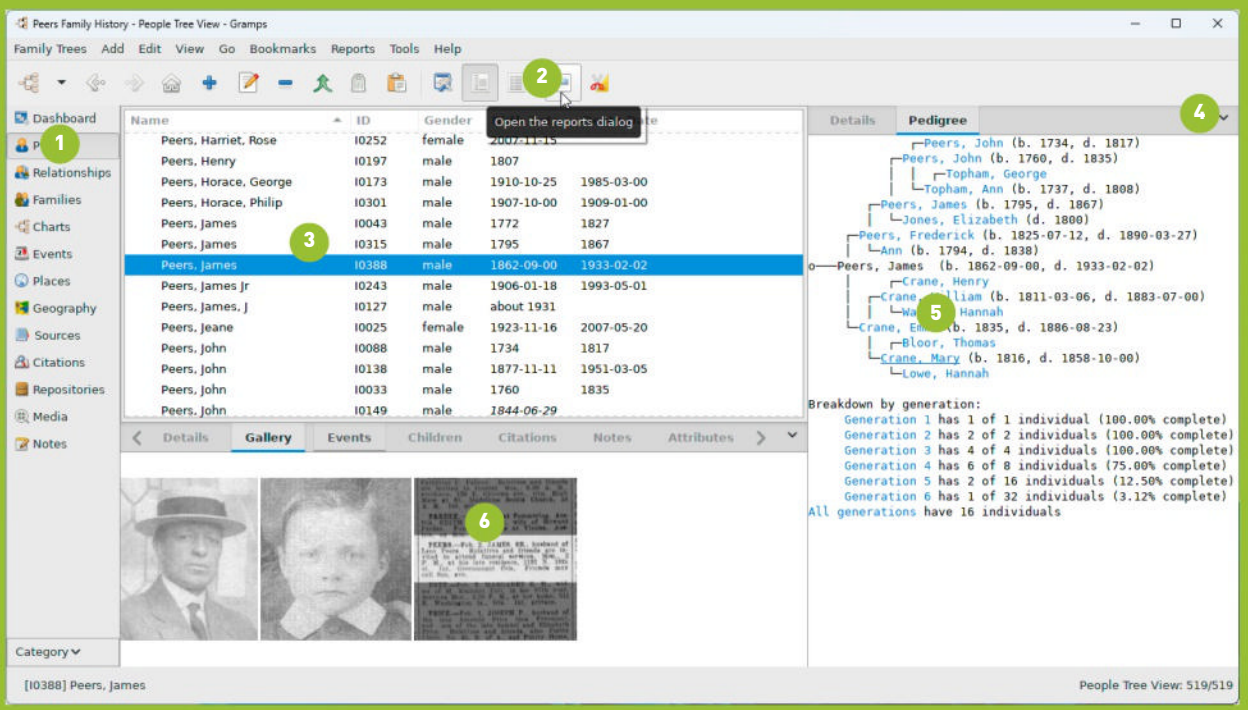
NAVIGATING GRAMPS



1. SWITCH VIEWS
Use the left-hand pane to switch between Gramps' main views—most are self-explanatory, while the Dashboard allows you to set up a whole page of customizable widgets called Gramplets.

2. CONTEXT-SENSITIVE
The view (and toolbar) changes depending on the view that has been selected—roll your mouse over a button for a pop-up description of what it does.

3. MULTI-PANED VIEW
Each view contains a two-paned window. On the left are details from the current view. You can click and drag the dividing line to increase or decrease the size of any individual panes.

4. SET UP GRAMPLETS
You can also choose to display specific Gramplets in the right-hand pane. Click the □ button followed by 'Add a Gramplet' to add your choice—each one is displayed in its own tab.

5. INTERACTIVE
Everything on screen should be interactive—click a person's name in the Pedigree Gramplet to jump to that person's entry or right-click to open their own Person editor window.

6. VIEW DETAILS
You can browse what you know about an individual in People view by selecting them, then using these tabs to see what information is recorded. Again, double-click an element to edit it.

» Now, switch back to the Events tab. This is where you record all the details and facts that make up each person's life from birth to death, including every significant event in between, from appearances in the documentary record (whether a census return, employment records, or—gasp—in front of a judge), to places where they lived, jobs they held, and so on.

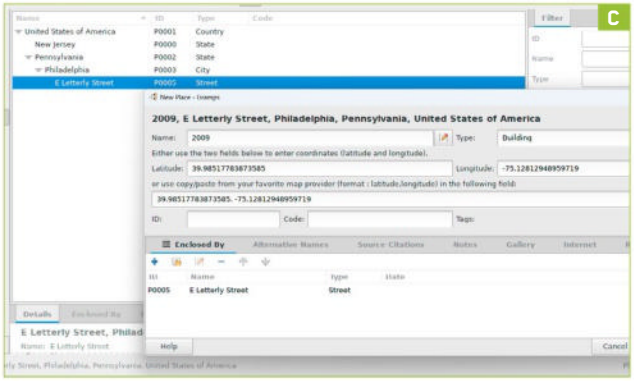
» Click +, and you'll see the Event Reference Editor window open with 'Birth' selected as the 'Event type'. All events—also known as 'facts' in genealogy circles—are made up of several elements: the type, date, place where it occurred, and a handy description field. You'll also see a tags option—these optional components allow you to set up your own system to help organize and find information.

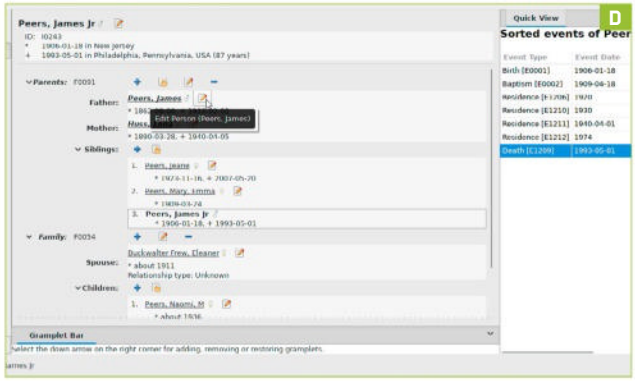
» Start by entering the person's birth date. You can type it in manually: YYYY-MM-DD (1975-12-25) for the exact date, or Mon YYYY (Dec 1975) for YYYY (1975) if you're not sure. Alternatively, click the date editor button to the right of the Date field for more options, as shown in [Image B], such as setting the date as an estimate or providing a date range (such as Oct-Dec 1975).

4 WORKING WITH PLACES

Once you've entered the date, it's time to record where the event occurred. Unlike some genealogy programs, Gramps doesn't let you record this as free-form text, but instead requires you to select from a database of place names to ensure that places are recorded consistently. It also preserves a strict hierarchy, with separate entries for each division (countries, states, cities, and districts, all the way down to individual buildings), which are then linked by a means of 'enclosures'. Confused? Don't be, it's quite straightforward: states are enclosed inside countries, cities and towns inside states, and so on.

» It's an elegant system, let down by the fact that no places are provided by default—you literally start with a blank slate, even with standardized places like states and countries. Thankfully, adding places isn't too difficult—click the + next to Place to start. First, enter the lowest level of the address you have—if you're recording a birth, for example, then it might be a hospital





name: enter the name, then set the Type dropdown to Building. You'll see spaces for recording latitude and longitude, allowing you to pinpoint the place on a map—you can get this information from a third-party website like Google Maps or Wikipedia for certain historic buildings, or you could install the Places and Co-ordinates plugin following the advice in the box about add-ons.

5 ADD PLACE HIERARCHIES

Once entered, click the + button on the 'Enclosed by' tab to create the next level in the place's address: a street name perhaps, or the village, town, or city. Click OK to see it appear. Click OK again and switch to Places view. You'll see the higher-level place name appear—click > next to it, and your original place will appear nested beneath [Image C].

» Double-click the higher level and repeat the previous step—clicking + under its 'Enclosed by' tab—to enclose it in a place name higher up (such as state). When inputting these higher levels, skip looking up geocodes, as they're only really needed for a precise street address, such as a building or street.

» Now you've entered your first event, move on to the next one. Again, choose a type, date, and place, but when you come to enter the place details, you can click 'Select an existing place' to choose a previously created place, as well as clicking + to create a new one.

» This can be time-consuming, so one way to speed things up is to set up your places manually via the Places view on the main screen. If they exist within an existing level—say a city—start by selecting that from the list before clicking + to create your place. This will then automatically be enclosed within the higher level.

» The Places view is also where you manage your places database—you can edit places from here, plus get a list of events they're linked to (look under References). If the place is geocoded, right-click it and choose 'Look up with Map Service' to view it on a map in your web browser.

6 MAKING CONNECTIONS

We'll return to adding more details to individual ancestors—photos, sources, and so on—shortly. For now, let's switch focus by adding other members of your family—children, spouses, siblings, parents, and so on. The quickest way to add additional people to your tree is to automatically link them together in families as you create them. To do this, select 'Add > Family'. Here, you'll be greeted with a new dialogue box from where you can add existing people or create new ones from scratch as parents and children within the family. You'll also find a 'Relationship option' dropdown allowing you to specify the nature of the parents' relationship: married, civil union, unmarried, or unknown.

» You'll also see an Events tab, where you can create (or link existing) events to family groups, as well as individuals. It works in the same way, so is perfect for recording shared events such as marriages or census returns. Once done, you can then link the shared event to all individual participants (bride, groom, and so on) too.

» Also, check out the Relationships view—select a person under People, and then select Relationships to view both their parents, siblings, and family (partner and children) [Image D]. This view may seem superfluous, but—like all of Gramps—it serves a purpose in aiding navigation. From here, you can switch active view to another individual (click their name), or use the pencil icon next to a name to perform some quick edits.

7 WORKING WITH SOURCES

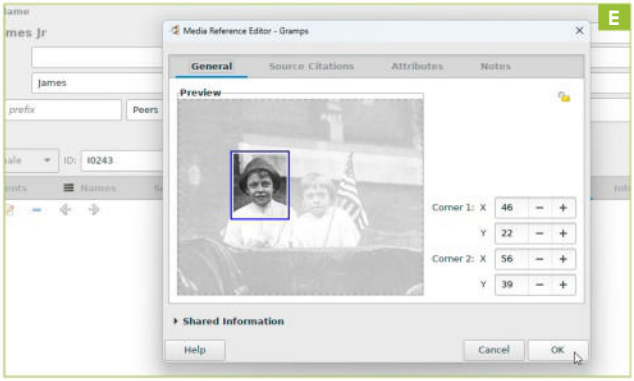
Family history is far more than simply compiling a list of names and dates to see how far back you can push your tree. Take the time to learn a bit more about your ancestors' lives using documentary evidence, and

PROVE YOUR CLAIMS

Family history is the ultimate detective experience: gather evidence (known as sources), and then use the information to fill out your family tree. This information is often referred to as 'facts' in family history circles, but a more accurate term is 'claims'. All good historians know you can't take information at face value—it should be assessed and compared with other sources for reliability and veracity.

Therefore, when you're recording events, it's important to provide supporting evidence, particularly when you come across conflicting information. To help you manage your sources, Gramps follows standard practice in providing you with repositories, sources, and citations. The source is the evidence you're using, such as a certificate, other official document, handwritten letter, or photo. These are stored in repositories to help you keep them organized—this might be a physical location such as a box in someone's loft or a certificates office, or a virtual location, such as a website.

Citations basically link a source to a specific piece of information: an event, date, place, or name, for example. This provides support for the claim being made. A single source can be linked to multiple citations in this way.



you'll be surprised at how you can quickly build up a rich picture of the kind of lives they led. Unlike other genealogy programs, Gramps doesn't link into third-party websites to hunt down and merge records into your tree, so this information needs to be entered manually—see the box for how sources work.

» Like other aspects of Gramps, you can set up sources and citations as you add events. When inputting details, go to the Source Citations tab and click + before clicking + to create the source itself. Use the Notes tab to transcribe specific information, and the Gallery tab to attach a scan or image of the document. Switch to the Repositories tab to assign it to a repository.

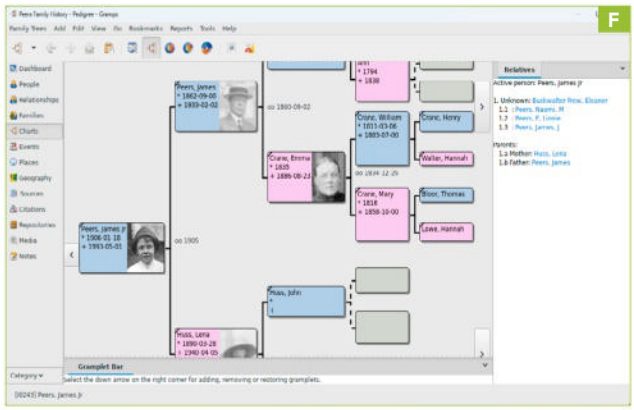
8 ADD MEDIA TO YOUR TREE

Nothing brings your family tree to life like a cache of treasured photos or documents shedding light on your ancestors' lives. Gramps lets you attach digital images to virtually all parts of Gramps, from individuals and families to places and sources—look for the Gallery tab.

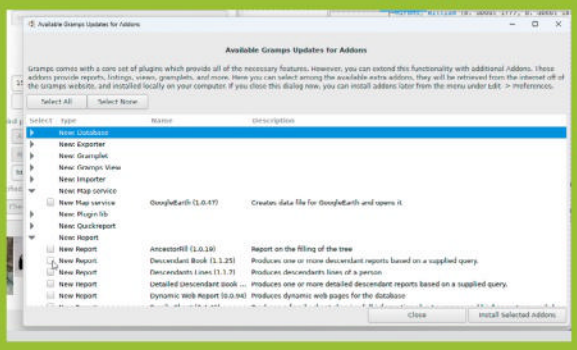
» Let's attach a photo of a person to an individual. Switch to People view and double-click a person to open their personal details window. Switch to the Gallery tab and click + to browse for and select a photo from your library. If you keep your photos organized in a single folder, check 'Convert to a relative path' before clicking OK to import the photo.

» The Media Reference Editor will open. One of Gramps' strengths is that it allows you to highlight part of the image—typically a headshot, linked to the individual. Drag this around the head [Image E]. To resize the selection, place your mouse near an edge or corner, then click and drag the red square.

» Expand the 'Shared Information' section to edit the photo's title and provide a date for when it was taken. Use the Notes tab to record more details—multiple notes can be attached, such as a story about the photo, notes identifying people in a group photo, or recording information on the back of the photo. Click OK.



TAKE GRAMPS FURTHER



Now you've explored the basics of Gramps and got to grips with its breadcrumb-like navigation system, powerful set of tools, and customizable user interface, keep digging. Make use of its Bookmarks system to add shortcuts to frequently accessed items—just navigate to the view you want and choose Bookmarks > Add Bookmark. Make use of the Go menu to retrace your steps through each view, and explore the Tools menu for options helping you analyze your data, plus perform various checks and—if necessary—repairs.

Also, take the time to select Edit > Preferences > General tab, and click 'Check for updated addons now' to browse a list of plugins that can extend Gramps' functionality further. Expand a category, read the descriptions, and check any plugins before clicking 'Install Selected Addons'. You'll find a wide range to choose from, particularly under Gramplets. To simplify locating and adding geocodes, for example, install both Places and Coordinate plugins under Gramplets and Gramps View respectively.

Don't forget to bookmark the Gramps Wiki (https://gramps-project.org/wiki/)—if you run into problems, you'll find detailed help here, including a section dedicated to plugins (click Third Party Addins from the left-hand menu).

» You can also link a single photo to more than one element, plus highlight different parts of it individually. When in the Gallery tab, click the 'Share' button instead of the + button to select an existing image to link to.

9 EXPLORING YOUR TREE

Once your tree takes shape, Gramps provides you with numerous ways to view your research. Select a person and click Charts, for example, to view a simple pedigree chart of the selected person and their immediate ancestors [Image F]. Use the Geography view to plot the selected person's life on a map, with each place highlighted using the geocodes you input earlier.

» When it comes to creating more meaningful insight, explore the Reports menu. These can be used to create graph-like displays, charts, or reports, which can be printed or exported as PDF or SVG files. You can also build a fully functioning website for offline use (load it on to a USB stick for another family member to browse), or to upload to your web space.

» Each report is fully customizable, and the number of options can be a little bewildering at first. Take our advice and experiment with settings producing PDFs if necessary, before committing anything to paper.

Master three great Thunderbird add-ons

YOU'LL NEED THIS

MOZILLA THUNDERBIRD
(Free, Windows/Mac/Linux)
Version 115 of the free email client, which you can download from thunderbird.net

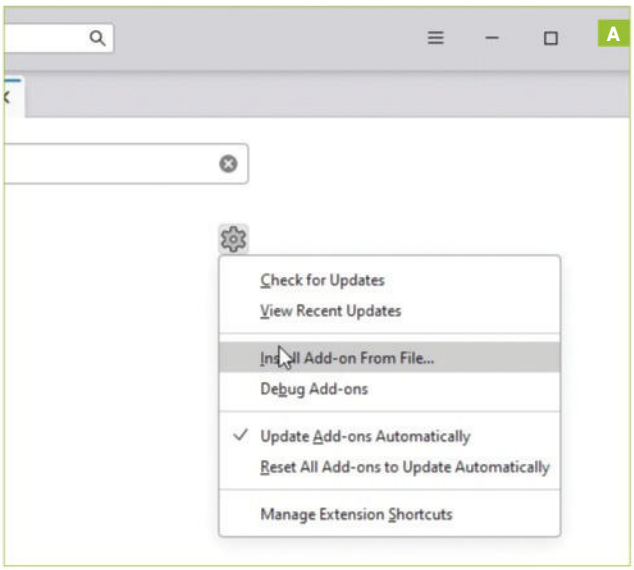
THUNDERBIRD HAS JUST BEEN UPDATED—the tabs of its old interface are still there, but you can hide them if you only have one component open. There's also a column of icons that switch between email, calendar, address book, and more; a handy search box in the title bar; and a discreet menu that saves you from picking your way through the full menu bar.

It's not just redesign for design's sake, though, as there are other changes that will make an appreciable difference to the way you manage your email. Chief among them is the new tags filter, which lets you more quickly identify particular messages. Say, for example, that you want to tag every security alert you receive as 'Important'. You can apply that particular tag to a message simply by pressing 1 when the message is open. You can apply a tag for Work, Personal, To-do, or Later by pressing 2, 3, 4, or 5 respectively.

Tags themselves aren't a new feature, but the 'tags folder' mode is (see annotation) . This lets you quickly isolate messages that have a specific tag. Even if you're only using the default tags and the five preset shortcuts, this is a quick and easy way to focus on work messages during the day, personal messages at home, or emails you've not had time to deal with earlier.

If the default tags don't fit the way you work with Thunderbird, you can change them. To do so, click the three-lines button again, then Settings. Click 'General' in the sidebar, then scroll down to Tags in the window's main pane, and click Edit.

Some features we'd really like to see still aren't included, but you can add these by installing add-ons. Here, we'll look at three must-have add-ons: 'Attach from Clipboard', Mail Merge and Send Later. –NIK RAWLINSON



1 INSTALL THUNDERBIRD ADD-ONS

We've provided direct links to each of the add-ons we'll be looking at, but if you want to install others, start by searching at addons.thunderbird.net. When you find an add-on you want, make sure it's compatible with the version of Thunderbird you're running, as detailed in the white box below the green Download Now button. If it is, click the button to download it.

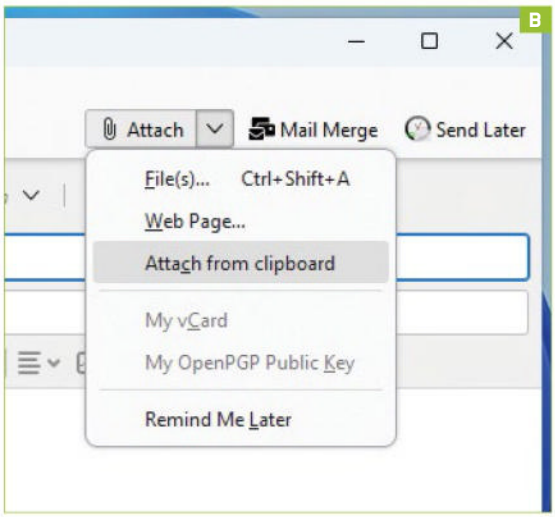
» Switch to Thunderbird and click the menu (three horizontal lines top right, [Image A], followed by 'Add-ons and themes'.

» Click the settings cog and select 'Install Add-on From File...' Navigate to the file you just saved to your Downloads folder (its file name will end .xpi), select it, then click Open.

» Thunderbird will warn you what rights the add-on has over your data. If you're happy with those, click Add, and as well as being integrated with Thunderbird, the add-on will be added to a list. This means you can temporarily disable it, should you want to, by clicking the slider beside its name.

2 PASTE FILES FROM WINDOWS AS EMAIL ATTACHMENTS

Thunderbird is clever at spotting when you've used the words 'attach' or 'attached' in an email, but haven't yet added a file. It will pop up a yellow warning banner, with a clickable link to add the attachment.



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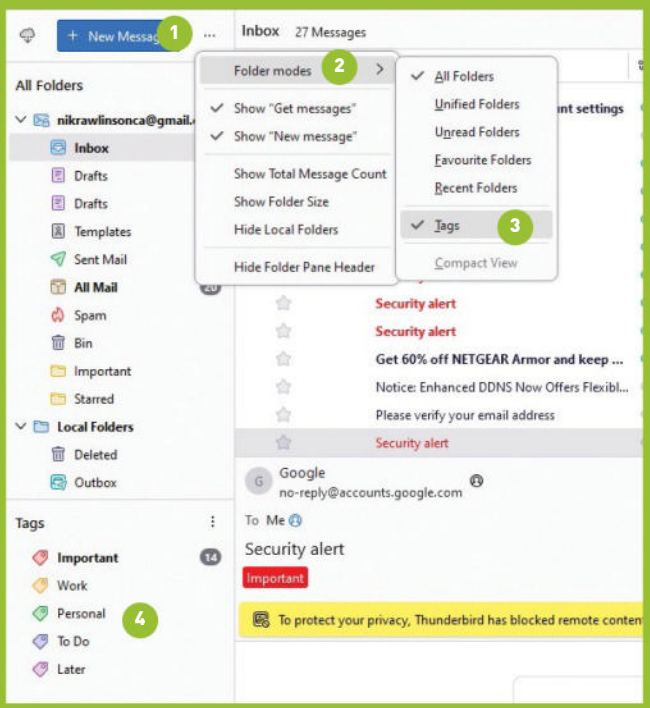
TAGS FOLDER MODE



1. NEW MESSAGE
You'll find it by clicking the three dots at the top of the mail module's sidebar, to the right of the New Message button .

2. FOLDER MODE
Having done this, hover the mouse icon over the 'Folder modes' option that appears.

3. TAGS
Theb, click 'Tags'.

4. DEFINED TAGS
A new panel will then appear in the sidebar showing your defined tags. When you click one of these tags, only messages carrying that tag will be shown in the inbox.

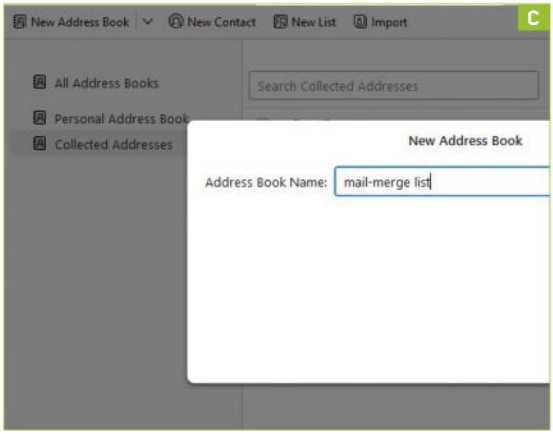
» This is handy, but copying attachments from Windows and pasting them directly into a message is even more convenient. That's exactly what the Attach from Clipboard add-on makes possible—install it from tinyurl.com/36tun82m.

» Once it's installed, open File Explorer in Windows and navigate to the file you want to attach. Remember, some email servers place limits on the maximum size of an email, so try to keep attachments to 5GB or less.

» If you want to go much beyond this, consider uploading them to an online-storage service instead and pasting a link into your message. Doing this not only makes it less likely that your email will bounce; it's also good manners, as it saves the recipient from downloading a large email the next time they check their inbox, which they may well have to do from their phone.

» Select the file, then press the usual Ctrl+C keyboard shortcut to copy it. Return to your email, click the down-pointing arrow to the right of the Attach button at the top of the interface [Image B], and select 'Attach from clipboard'. The file will then be attached to your message.

» However, this isn't only useful for adding files copied from File Explorer—you can also add screenshots as attachments. Press the Print Screen (PrtScn) button on your keyboard, and



Windows will copy it to your clipboard. If you were to press the regular Ctrl+V shortcut (for paste) while writing your email, the screenshot would be added to the body of the message, which might not be the formatting you want, especially if it's particularly large.

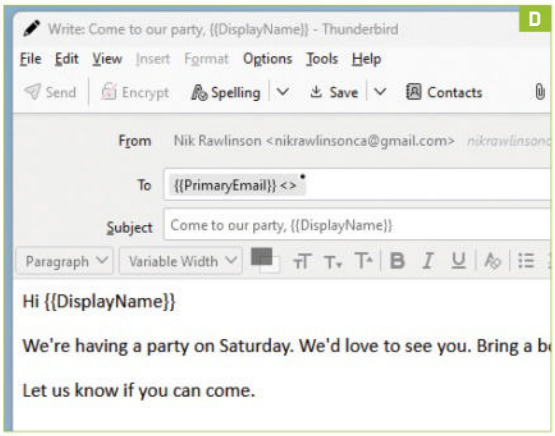
» If you'd rather add it as an attachment, press the Attach arrow at the top of the interface, and again click 'Attach from clipboard'. In doing so, you've just saved yourself the trouble of having to navigate through your folders to find the image.

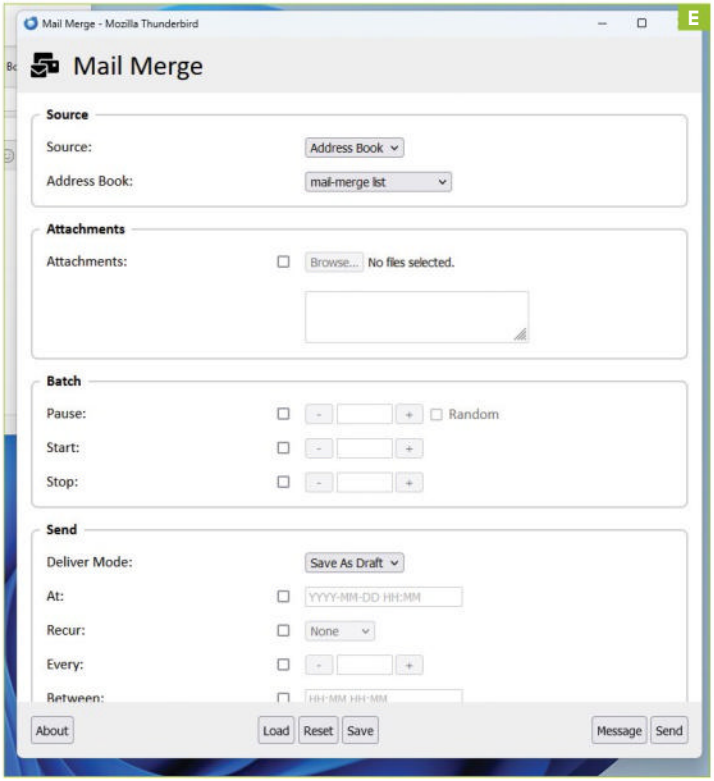
3 SEND PERSONALIZED EMAILS TO MULTIPLE PEOPLE

When you need to send the same email to several people—like your extended family or a club membership list—it's much nicer for the recipients if they've been addressed personally. You could copy and paste the same text into several separate emails and change the opening line manually, or use the Mail Merge add-on instead.

» Install it from tinyurl.com/2jz5y4wr, then switch to the Thunderbird address book by pressing Alt+2. Because the Mail Merge add-on sends messages to every member of a specified list, you probably don't want to use your master address book where the distribution list is almost certain to include several people who shouldn't receive your message.

» Creating a new address book only for specified recipients gives you control over who sees your message. Click 'New Address Book' at the top left [Image C], and give your new book a name.





» Add the relevant contacts to your new address book or, if they already exist in another address book inside Thunderbird, find them there, then drag them across into the new one. Hold down the Ctrl key while dragging to make a copy of the contact in the new address book if you don't want to remove them from the original one.

» Now, switch back to your inbox by pressing Alt+1 and start a new email. Type any variables inside two curly brackets {{ }} for placeholders that you want to replace with live data drawn from your new address book.

» Variables you can use include {{DisplayName}} [Image D], {{NamePrefix}}, {{FirstName}}, {{LastName}}, {{PrimaryEmail}}, {{JobTitle}}, {{Company}}, {{BirthYear}}, and so on. Find more in the 'Addressbook Properties Supported by Thunderbird' section on Mail Merge's download page (tinyurl.com/2jz5y4wr).

» When you've finished writing your message, click Mail Merge. Select the new address book containing the contacts [Image E], then select Save As Draft, and click Send at the bottom.

» Mail Merge will now show you how many people will receive your email. Click 'Send' again, and it will replace your placeholders with data pulled out of your selected address book, saving each individual message to your Drafts folder. You can cast an eye over them there to make sure they've been correctly processed before sending them.

4 SCHEDULE EMAILS TO BE SENT LATER

At the time of writing, Thunderbird 115 is so new that some add-ons are still trying to catch up with it. The excellent Send Later (tinyurl.com/yn9hby3t) is among them. The version in the official add-ons store only works with Thunderbird 114, so we installed a preview version instead. Do this by visiting extended-thunder.github.io/send-later/ and clicking the Beta button. It worked fine in our version of Thunderbird 115.

» Write and address an email in the usual way, but rather than clicking Send, click Send Later [Image F]. Now, either set a time and date when you want the email to be sent, or type a more general description—such as 'five minutes from now', '9am tomorrow', or 'in an hour'. It can recognize scheduled instructions like these written in plain English.

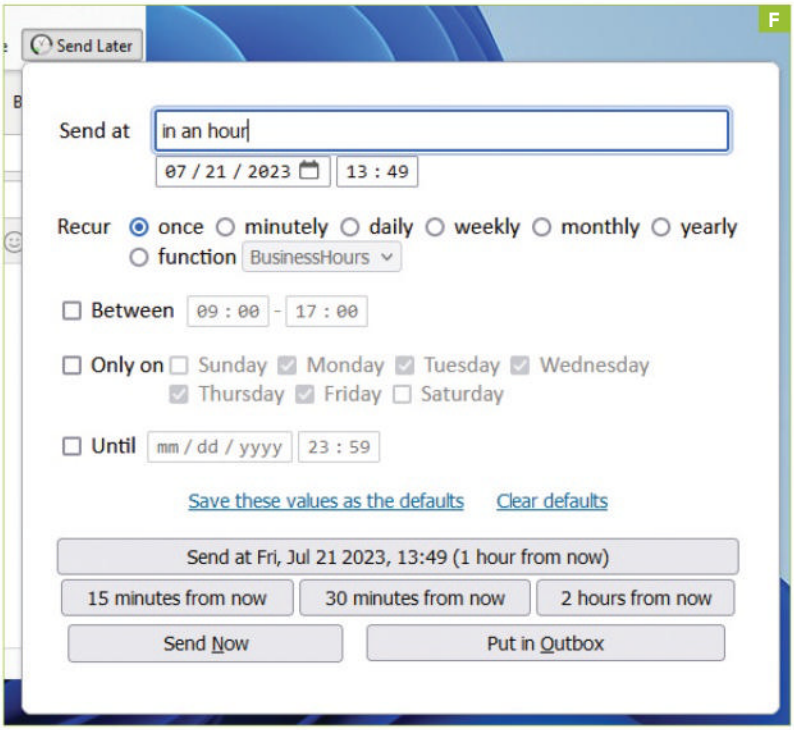
» One handy use for Send Later is to set reminders for yourself. Let's say you need to remember to take medicine at a specific time every day. In this case, you'd write an email to yourself, click Send Later, and specify an appropriate time to send the message. Then, click 'daily' on the Recur line, and the message will be set to repeat.

» As you'll see, there are also options to send between specified times and on specified days, and to enter an end date if you've set up a repeating message.

» Because Thunderbird still has to send the email, you'll need to leave your computer switched on and awake, and also keep the program running. When our computer went to sleep, some of our test messages weren't sent until we woke it up again. Keep this in mind if you're sending something that is genuinely time-sensitive.

» When you've specified the dispatch time as precisely as you can, click the 'Send at' button and Send Later will add it to a queue.

» If you have several messages queued to send later, you can check what they are and when they'll be sent by clicking the Send Later button that's been added to the toolbar at the top of the inbox screen.



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Use Generative Fill in Photoshop Beta

YOU'LL NEED THIS

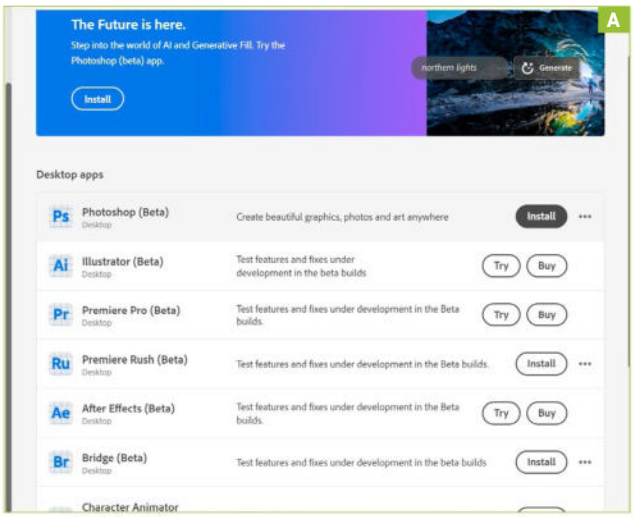
AN ADOBE CREATIVE CLOUD OR PHOTOSHOP SUBSCRIPTION
Adobe (www.adobe.com)

YOU CAN'T THROW A GRAPHICS card these days without hitting some mention of AI with it. While the large language model chatbots may give every indication of understanding what you say and being able to hold a conversation that could pass for a real human, it's in the world of image generation that AI's strengths are most clearly on view.

Image generation involves a text-to-image model such as Stable Diffusion or Midjourney taking a text prompt and turning it into an image. You can be as vague or detailed as you like, specifying the style of image you want to see or leaving it up to the AI to provide a creative interpretation.

Adobe has just integrated a Generative Fill command into Photoshop, where it makes use of the creative software giant's Firefly cloud service to add new backgrounds and objects into images, as well as being able to remove existing ones.

It's all neatly blended into the app too, with the new content appearing on a new layer to be integrated into your final composition. Especially good for creating ideas at the beginning of the creative process, the Firefly AI is trained on Adobe Stock images, openly licensed work, and public domain content rather than copyrighted content from the web. –IAN EVENDEN



1 GET THE LATEST VERSION

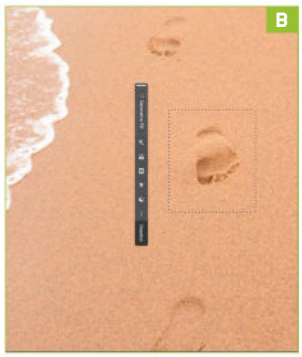
You'll need the latest version of Photoshop for this, as Generative Fill has only just come out of beta. To get it, open the main Adobe Creative Cloud app and make sure your copy of Photoshop has been updated. The version we installed was the version 25 release, but use whatever version is available as you're reading this. When we wrote this guide, we were using the Beta version of the software [Image A], but now it's available in the full stable version. Open the app for the first time, and you'll get a slideshow that talks you through the new AI capabilities so you know where to begin.

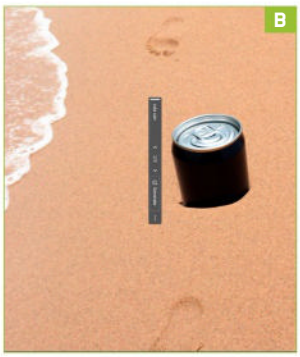
2 MEET GENERATIVE FILL

Adobe's new toy is in some ways the next generation of its context-aware tools that can extend the edges of an image being cropped to a new aspect ratio or filling a space where something used to be. However, instead of merely iterating on what's already there, Generative Fill can create entirely new objects. The simplest way to find it in Photoshop is to make a selection. Adobe's new floating toolbar appears next to the marching-ants border you've created [Image B], and Generative Fill will be on the left. It's a text input box, so you can type anything into it (it supports over 100 languages), and have the AI act on your instructions. Leave it blank, and Firefly will fill in the selection based on its surroundings, just like Context Aware Fill.

3 TRY THE FILLING

As the test image we've chosen shows footprints on the seashore, we're going to remove one of them, and try replacing it with other items. Our first prompt is 'cola can', which gets us [Image C]. It's not very good, but we weren't very specific. An improvement that Generative Fill brings over Context Aware Fill is that you get three variations, which you can switch through using the Properties palette, which also shows your prompt, or using the floating toolbar. One of the variations shows the can placed upright, casting a shadow onto the sand that points away from the brightest part of the image. Sadly, the ring-pull at the top has succumbed to AI weirdness, and doesn't look right, despite casting its own shadow. The top of the can is also much too deep, with a tall rim rising up around it that would make it undrinkable. Still, it's a good start from a two-word prompt.





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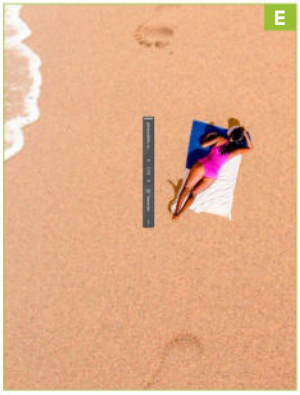


THINGS YOU CAN'T DO

There are limits to this creativity, however. Just as ChatGPT acts within constraints to what it can talk about and the answers it can give, Firefly won't generate certain images. There's definitely a banned word list in play, though Adobe is being opaque about what it is. One online user reports being unable to generate a sextant—a tool used to find your position at sea, and nothing to do with adult content. When trying to create some fireworks to go in the sky above a city, we used the prompt "explosions", and were greeted with an error message not unlike "I'm sorry, Dave. I'm afraid I can't do that". The correct prompt turned out to be "fireworks".

4 GENERATIONS

The prompt "red drinks can half buried in sand" gets us [Image D], which is much better, with a reflection that once again respects the lighting in the image, and could be overlaid with the logo of a well-known cola company, although the ends are a little uneven. The two variations provided are both seen from the top, and one makes the top of the can so small it would be impossible to drink from. The prompt 'crushed red drinks can' provokes a misunderstanding from Firefly, which creates a top-down view of what appears to be a paint can filled with red granules or powder.

5 PEOPLE POWER

All this generating of drinks cans is fine, but AI image generators are known for their ability to create uncannily realistic people. Can Firefly do the same? The prompt "photrealistic sunbather laying on towel"—complete with typo—gets us better results than when we correct it, with one of its variations being [Image E]. The position of the sunbather between the footprints, combined with her position as if she's getting up, suggests a giant has just stepped over her. She's not particularly photorealistic, however, and the shadowing is all wrong, but other versions are much worse, with mismatched legs, webbed hands without fingers, and frankly bizarre body positions. Your generated object appears on its own layer, so it's possible to move it around or blend it in to the rest of the image using the standard Photoshop tools.

6 BACKGROUNDS

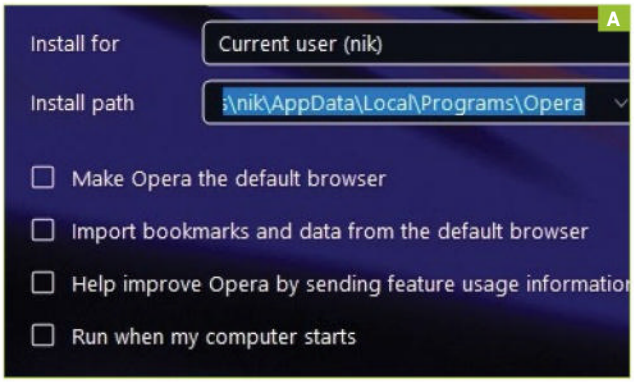
Being able to remove and replace the background of an image is an important part of any image editing workflow, and Firefly can help. We opened the portrait on the left in [Image F], and used the Remove Background command from the floating toolbar to cut the subject out onto its own layer. Then, selecting the whole of the canvas, we gave Generative Fill the one-word prompt 'woodland', which produced the image in the center. From here, we selected the lower half of the image and prompted "dry stone wall", which we expected to create a rustic wall that would fulfill the role of the concrete in the original image, appearing in front of the subject. However, Firefly displayed some creativity, and filled in the rest of the subject's body so she's standing in front of the wall. Nowhere in the prompt did we mention that she was wearing jeans, and it has filled in the bottom of her shirt and jacket too. At first glance, it looks real. Another variation extended her shirt downward into a dress, and continued the striped pattern of her jacket further, while the third tried to insert a cat into the image too, but only managed a strange furry smear.

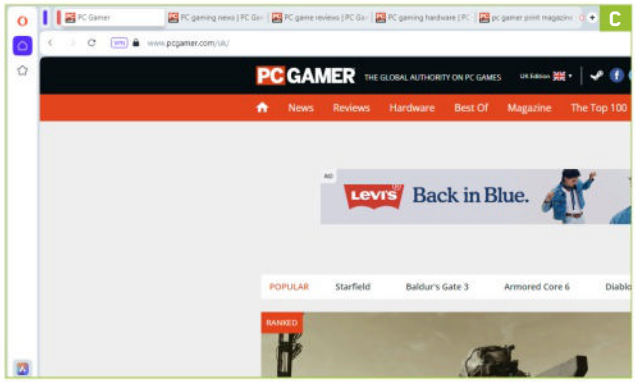
Use tab islands in Opera

YOU'LL NEED THIS

OPERA ONE
www.opera.com/browsers/opera (free download)

OPERA HAS BEEN UPDATED. The browser, now known as Opera One, has a fresh new look on Windows, MacOS, and Linux thanks to its innovative new feature: tab islands. This lets you open multiple links from a single page and keep them in a group. This means they will be kept separate from links you open on other sites or that you type directly. Once you get used to it, tab islands will help you speed up online research, holiday planning, comparing the price of train fares, or delving into Wikipedia pages. Here, we'll show you how to get started and reveal the keyboard shortcuts that will help you manage your tabs more efficiently. –NIK RAWLINSON





1 INSTALLATION AND CONFIGURATION

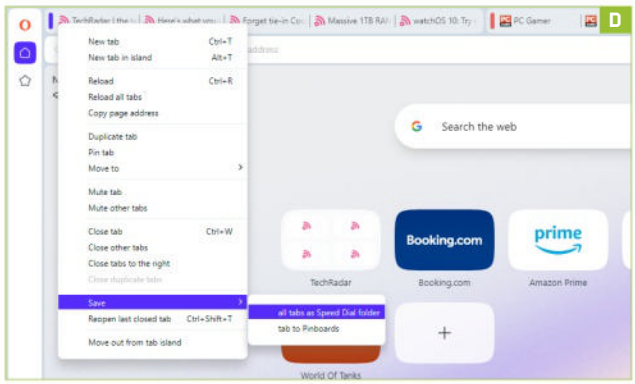
Download the new version of Opera from www.opera.com/browsers/opera. When it's finished downloading, double-click the 'OperaSetup.exe' file in your Downloads folder and follow the installation instructions. Note that there are several hidden options you might want to change [Image A]. Untick the relevant options on the first screen if you don't want to make Opera your default browser, send usage information to Opera, or start the browser when your computer boots. On the following screen, click 'Configure in settings' if you don't want to share your interests based on the websites you visit or search for, and your location, and whether you want to opt out of personalized ads and ads based on your interests.

2 TRY ALL THE DIFFERENT FEATURES

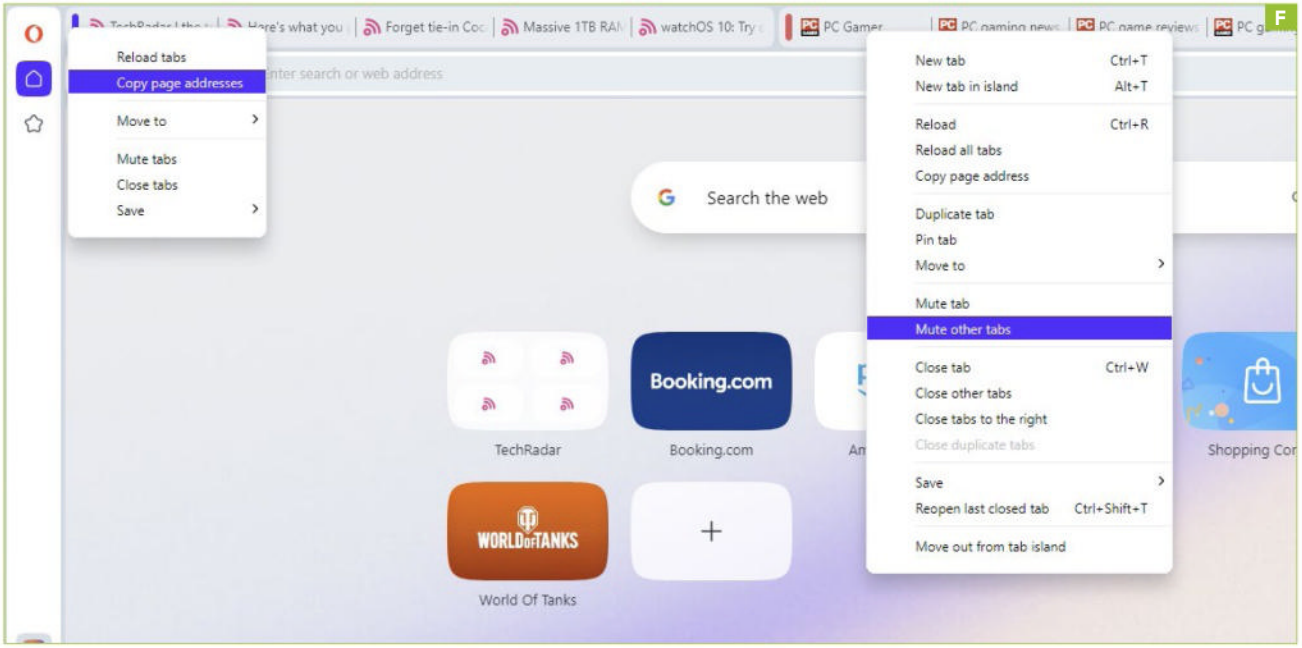
When installation has finished and Opera launches, click Get Started and work through your options. When you reach the browser homepage, visit our sister site Tech Radar at www.techradar.com [Image B], which is a good place to learn how the new tab islands feature works. Hold down the Ctrl key while clicking three or four links to open each one in a new tab at the top of the program window. Notice how there's a purple bar to the left of the first tab. This is the header for the group of tabs you've just opened—or 'tab island', as Opera refers to them.

3 CREATE AND VIEW TABS

Click the + in the circle to the right of your tabs [Image C]. This creates a new tab outside of the existing tab island. Now, visit www.pcgamer.com and repeat what you did with the TechRadar homepage (clicking several tabs while holding down Ctrl). After this, you'll see a red bar to distinguish this new separate tab island. You can use these bars to save space in the



© WWW.OPERA.COM



browser window. Click the purple bar, and the TechRadar tabs will collapse, as you can see here, leaving only the PC Gamer tabs in full view. When you want to restore the TechRadar tabs, click the purple bar again. Likewise, clicking the red bar will collapse and expand the PC Gamer tabs.

4 SAVE TABS

If you regularly use a handful of pages that you intend to open every time you browse, save them as a folder. Open the pages in a single tab island, then right-click the island's header, hover over Save, and select 'tabs as Speed Dial folder' [Image D] in the menu. They will be added to the homepage that appears when Opera starts. To change the name of the folder (from the default 'Folder'), hover over it and click the three dots that appear. Click 'Edit' on the menu, and type a new name.

5 CREATE SHORTCUTS

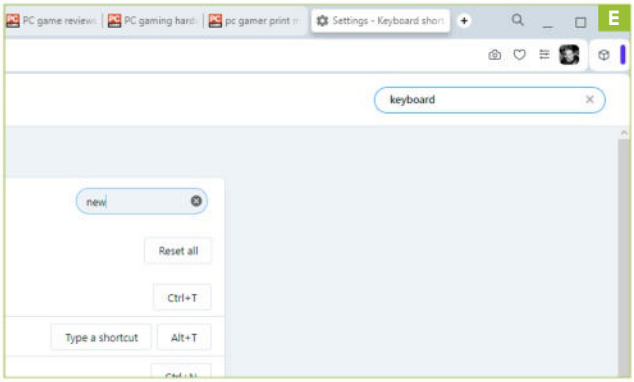
Tabs are a common feature across all browsers, with most using Ctrl+T as the shortcut for creating a new tab. Doing this in Opera creates a tab outside of any island, and it's supplemented by a second shortcut (Alt+T) that creates a new tab within the active island. If you want to change this, click the Settings button [Image E], scroll to the bottom of the panel, and click 'Go to full browser settings'. Type keyboard shortcuts in the search box and click 'Configure shortcuts'. Scroll down to 'New tab in island' and click 'Type a shortcut'. Press the key combination you want to use instead of Alt+T.

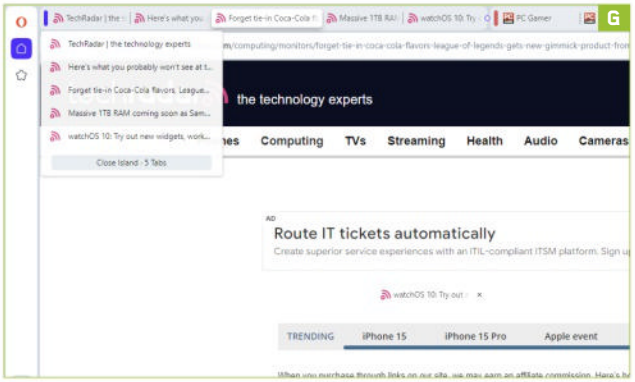
6 CONTROL TABS SIMULTANEOUSLY

When multiple tabs share a single island, you can control them simultaneously [Image F]. Right-click the tab header and you can refresh all tabs, which is useful if you're using them to monitor scores in several live sporting events. You can also copy their addresses if you've been using them for research or you want to share several holiday options with a friend. Right-clicking a single tab gives you an option to mute it or, alternatively, to mute all other tabs if several are playing media simultaneously .

7 CLOSE DOWN TABS

When it's time to clean up, you can shut down an island with one click [Image G]. Hover over its tab until the menu appears, then click the Close Island button. If you only want to close a single tab, hover over it and click the 'x' that appears. Should you want to focus on a single tab, you don't need to close all of the others: simply click, hold and drag it out of the island, and it will detach from the current browser window to sit in a window of its own.





LAB NOTES

JEREMY LAIRD, CONTRIBUTOR

Too much of a good thing

Gaming monitors are getting dangerously big

CAN YOU HAVE TOO much of a good thing? Turns out the answer is yes. I was putting the hot new Samsung Odyssey Neo G9 G95NC through its paces for a sister title to *Maximum PC*, and had a bit of an accident.

The G95NC, you see, is the new 57-inch monster with that ridiculous 32:9 aspect ratio and outrageous 1000R curve. We've seen similar displays from Samsung before, but only up to 49 inches. Now, you might think that's just a case of massive and, er, massiver. 49 inches is huge, right?

Yes, it is. But somehow, this new 57-inch model feels even more dramatic than the step from 49 inches to 57 implies. It also happens to create logistical issues. Repackaged TVs aside, this is the most physically cumbersome gaming monitor I've ever wrestled with, partly thanks to it being a LCD panel with a mini-LED backlight.

While moving it to another room, the panel cracked. Portability obviously isn't a selling point, but this fragility does imply a technology being pushed to its limits.

Breakages aside, the Samsung Odyssey Neo G9 G95NC delivers an experience like no other display. With its dual-UHD resolution, it's essentially two 32-inch 4K monitors fused into one, right down to the 140DPI pixel density. In the past you could have a huge display or crisp fonts, but not at the same time. Now you can, and it's stellar.

So much image detail on such a huge screen is hard to process. In theory, this screen is capable of 240Hz. In practice, good luck running *Cyberpunk* with ray tracing at 240fps. In case you haven't done the math, the G95NC has over 16 million pixels. At 240Hz, that means just under 4 billion fully rendered pixels per second. That's only even theoretically possible right now with an AMD Radeon 7000 series GPU, because to hit 240Hz you need DisplayPort 2.1. Anyway, I now believe you can have too much of a good thing when it comes to gaming panels. If you don't hear from me, I'm on the run from Samsung's legal team.

Too big to handle: the monstrous new Samsung Odyssey Neo G9 G95NC.

SAM LEWIS

Staff Writer

I'm not sure what I think of Framework's modular laptops. I love the idea of an easily upgradable laptop where everything is designed to be removed and replaced, but in my experience, the best laptops are tightly integrated.

Anyway, Framework recently announced that it has stumbled on a bunch of old new-stock motherboards from its original 13-inch model when it was closing out the Compal factory in China it used for the subassembly of the first systems. It took those boards to its Taiwan factory, processed them, updated the firmware, and is now shipping them out at a hefty discount in order "to get them out into the world faster and ensure they don't go into waste."

We're talking Intel Tiger Lake era 10nm CPUs with four cores and eight threads. The board is just $199. You'll have to add some RAM and an SSD, plus a super-slim Cooler master custom case for $39.99, and a Frame and $49 power adapter. It even has Vesa mounts, so you could attach it to a monitor and create an all-in-one rig.

I'm not sure it would work out much cheaper than a ready-made mini PC, but the sense of creating something from what would have ended up as ewaste is satisfying, as is knowing that you'll have lots of options for future expansion and upgrades thanks to Framework's modular philosophy and emphasis on backwards compatibility.

© SAMSUNG

Samsung's updated Galaxy Tab S9 really gives that premium feel.

Editor's Pick: Samsung Galaxy Tab S9

The new best Android tablet

IT WAS NOT long after joining this publication that I reviewed Samsung's flagship Android tablet, the Galaxy Tab S8 Ultra. I found that the $1,100 device had a gorgeous OLED screen, but was a little too large in size and price for the average consumer.

Jump forward a year and a half, and that high-end screen tech has filtered down to the standard model of its successor, the Galaxy Tab S9, which is far more palatable at both $800 and 11 inches in screen size. Overall, it may be Samsung's entry-level tablet, but this upgraded display and the improved rear camera make it feel like a much more premium slate.

There are other new features worth noting, including a sturdier design that's dust and water-resistant, as well as a faster Qualcomm Snapdragon 8 Gen 2 processor, which is top of the line when it comes to non-Apple mobile processors.

The basic model comes with 8GB of RAM and 128GB of storage, but my version is the 12GB/256GB model. The storage element isn't worth worrying about, as the tablet has a microSD slot, meaning you can add more at a relatively low cost if you want to store lots of games and media. 8GB of RAM is a little on the low side in 2023, but my Samsung Galaxy S23 Ultra phone is no slouch using such a memory configuration and the same processor. Samsung does lots of promotions around its products, though, so if you can afford the higher-memory version, go for it.

At $799, the new Galaxy Tab S9 costs $100 more than the Tab S8. While the price bump isn't ideal, it's not an exorbitant hike, and that screen makes a good argument for the increase. The new OLED display looks phenomenal, and is much more colorful and vibrant than on the previous model. The videos I've been watching in HDR from Netflix look brilliant, with great separation between dark and bright.

At 10.01 x 6.53 x 0.23 inches and a weight of 1.10 pounds, the Galaxy Tab S9 feels like an elegant slab of aluminum; sturdy and great to hold. Given its slim profile and light weight, you should be able to comfortably hold this tablet for long stints. If you're doing lots of work, you may want to go for the 12.4" Tab S9 Plus. I found the accompanying keyboard accessory from Samsung felt less cramped, and you get more screen space for multitasking applications. Like predecessors, the Tab comes with DeX, Samsung's Windows-like laptop experience with which you can use a keyboard and mouse. It won't replace a laptop, but it's a great feature, and a real differentiator against Apple's iPad Pro.

Likewise, it's great that you get an S Pen stylus, which is an optional extra for Apple's tablets. The new S Pen has a lower latency of 2.8ms. If you want to use the tablet by the pool or at the beach, you can rest easy knowing that both the S pen and tablet have an IP68 waterproof rating.

The tablet boasts an 8,400mAh battery, which is a bump up from the 8,000mAh of the Tab S8. The OLED screen is a greater battery draw than before, but you get around eight hours of web browsing and six and a half hours of video playback.

Thanks to its sturdy build, slim design, and sharp and vibrant display, I can recommend the Galaxy Tab S9 for anyone looking for an 11-inch Android tablet. iOS users will obviously want to stay within the Apple ecosystem, but if you're agnostic, this offers much better value for money, and a really well-rounded package. **–GC**

$800, www.samsung.com

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Reviewed...

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78 Samsung Galaxy Book3 Ultra

80 OneXPlayer OneXFly

82 Asus Vivobook Pro 16X

84 WD Blue SN580

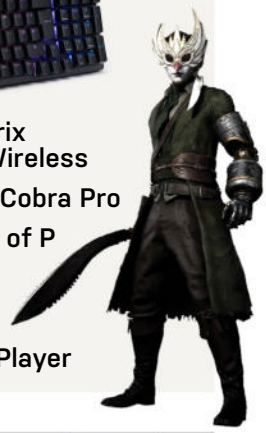
86 XGIMI Horizon Ultra

88 Asus ROG Strix Scope II 96 Wireless

89 Razer Cobra Pro

90 Lies of P

92 VirtualBox vs VMware Workstation Player



AMD Radeon RX 7800 XT

The best $500 GPU around

HOW MUCH VALUE do you put on ray tracing as a PC gamer? That's got to be at the forefront of your mind if you're considering dropping $500 on an AMD Radeon RX 7800 XT. If you are sold on ray tracing, you probably need to consider whether you're willing to pay another $100 for extra RT performance and drop the cash on the RTX 4070 instead.

If, however, you're convinced that rasterized performance is the only GPU metric worth a damn in this topsy turvy world of PC gaming, then the RX 7800 XT is probably the best upper mid-range graphics card you can buy today. We effectively now we have four graphics cards capable of very similar frame rates: the RX 7800 XT here, the RTX 4070, and then the RTX 3080 (which is pretty much end-of-life now), and RX 6800 XT from the previous generation.

The reductionist way of looking at the RX 7800 XT is that this new generation of Radeon GPU is delivering the sort of performance we had to pay $650-$700 for last time around, but that's still a pretty tantalizing way of looking at things. By offering frame rates akin to both the RX 6800 XT and RTX 3080, this price point is looking more potent than ever before.

In terms of current-gen head-to-head with the RTX 4070—itself delivering RTX 3080 frame rates with benefits—you're getting straight raster performance in games that is broadly similar (and sometimes higher), but for $100 less.

That should make it a very straightforward win for AMD, and the RX 7800 XT a card that ought to fly off shelves. Were it just about the raw silicon, maybe that would be the end of it, but there is more to the modern GPU ecosystem than just stream processors these days, and it would be foolish not to talk about the competing feature sets and strengths of AMD and Nvidia's latest cards.

However much AMD would like you to know that it has improved the ray tracing performance of its RDNA 3 architecture, with silicon dedicated to accelerating the RT pretties, it's still a generation behind Nvidia at best. When you throw heavily ray- traced games into the benchmarking mix, Nvidia's RTX 4070, and to a lesser extent the RTX 3080, takes the lead.

Right now, there are far more positives in the RX 7800 XT corner than the competing RTX 4070: It regularly wins out on straight raster frame rates, it has more video memory, which is a consistent theme of gaming today, and it has its own solid upscaling tech in FSR 2.2, with imminent updates on the way.

It's also $100 cheaper, which is probably the real kicker. If the two cards were closer in price, then the Nvidia ecosystem would have more pull. But until Nvidia drops the price on its RTX 4070, the RX 7800 XT is looking like the best bet for most PC gamers right now.

AMD wants you to know that this is a 1440p graphics card, designed to top 60 fps in the latest titles at the top settings. Honestly, it goes well beyond that, outside of *Cyberpunk 2077*. The RTX 3080, RTX 4070, RX 6800 XT, and RX 7800 XT all trade blows throughout the benchmarks at this level, showing how close these cards are, and it's pleasing to see the RX 7800 XT as the cheapest one sometimes leading the way, too.

It's also important to note how far ahead of the next one down the GeForce stack this Radeon GPU is. Compared with the RTX 4060 Ti, the RX 7800 XT is around 25 percent quicker for another 25 percent on the sticker price. Its relative performance against the RX 7700 XT is a nail in the coffin for its Navi 32-toting brethren. On average, we saw a performance deficit of around 20 percent, but the price delta is 10 percent.

This is a very good graphics card for non ray-traced gaming, and the highest performance from a sub-$500 card. But with a multi-chip GPU that isn't moving the game forward, all it really has over the competition and its last-gen stablemate, is that lower price. –**DAVE JAMES**

VERDICT 8

AMD Radeon RX 7800 XT

+ MID-RANGE MARVEL Great 1440p performance for the money; Full 16GB / 256-bit memory subsystem; Quiet.

– STUCK IN A RUT Ray tracing performance still lacking; Hotter and thirstier than Ada; Not a huge improvement gen-on-gen.

$499, www.amd.com

BENCHMARKS

	RX 7800XT	RX 7700XT	RTX 4070	RTX 4060Ti
Cyberpunk 2077 RTX (fps)	27	23	**39**	26
F1 22 RTX (fps)	67	58	**71**	54
Far Cry 6 RTX (fps)	**119**	102	110	96
Metro Exodus Enhanced (fps)	80	68	**87**	66
Warhammer Total War III (fps)	**96**	79	90	68
Tiny Tina's Wonderland (fps)	108	88	**113**	86

Best scores are in bold. Our test bench consists of an Intel Core i9 12900K, Asus ROG Z690 Maximus Hero, 32GB G.Skill Trident Z5 RGB DDR5-5600 RAM, 1TB WD Black SN850/4TB Sabrent Rocket 4Q SSDs, and Windows 11 22H2. All tests were done at 1440p resolution at highest or ultra settings.

SPECIFICATIONS

Architecture	RDNA 3
Manufacturing process	5nm GCD + 6nm MCD
Transistors	28.1 billion
Compute units	60
Shaders	3840
ROPs	96
Infinity cache	64MB
Memory	16GB GDDR6
Memory speed	19.5 Gbps
Memory bus	256-bit
TBP	263W

It competes with the best GPUs of this or any other generation.

Connections include USB-A, HDMI, and microSD card.

Samsung Galaxy Book3 Ultra

Watch out MacBook Pro; Samsung has you in its sights

SAMSUNG'S NEW ULTRA LAPTOP sits at the top of its laptop range, boasting a new design. There are suitably heavyweight components to match its name. Samsung sent us the top-end model, with a Core i9 processor and GeForce RTX 4070 graphics that push it into gaming laptop territory, most notably the 2023 Razer Blade 16. It also packs enough multi-threaded performance to make it a worthy alternative to the 16-inch MacBook Pro.

I mention these two rivals because Samsung has emphasized the slick dimensions. It's impressive and unusual to see such powerful components inside a sub-17mm design, and at 1.8kg it's light, too; the 16-inch MacBook Pro weighs 2.2kg, and the Blade 2.5kg.

Samsung has even slimmed down the power supply by choosing a phone-style USB-C charger. It's still meaty, weighing 370g, but it has to be to deliver 100W of power. It took the Book3 Ultra from empty to full in 75 minutes, which is a great result. You may not even need to put it in your bag: the laptop lasted 10 hours and 37 minutes when looping a video, and 9 hours and 30 minutes in light-use tests.

The aluminum chassis finished in dark gray would slot in next to a MacBook. It includes a USB-A port (on the right-hand side) to accompany the two Thunderbolt 4 USB-C ports on the left. You even get a HDMI output and microSD card slot.

Then we come to the 16-inch screen. This uses AMOLED technology and includes 2,880 x 1,800 pixels, and a 212ppi density ensure everything looks sharp. Samsung includes a bunch of color options, so it's easy to swap between Vivid (native), Natural (SRGB), Photo editing (Adobe RGB), and Movie (DCI-P3).

Keen gamers may not be impressed by the peak 120Hz refresh rate when rivals such as Razer and Asus offer 240Hz, but 120Hz is enough for a solid image. The laptop packs a 60W version of the GeForce RTX 4070. It's a fast GPU, but it's humbled next to the RTX 4080 in the Razer Blade 18 or the RTX 4090 in the Asus ROG Strix Scar 18. For example, the Samsung scored 9,142 in 3DMark Time Spy, compared to 15,300 for the Razer and 18,327 for the Asus.

That means you'll need to switch to 1080p, or drop to lower-quality settings, if you want 120fps frame rates. Take *Shadow of the Tomb Raider*—at 1080p with High settings, it averaged 135fps; at native resolution, this dropped to 84fps. Switching to Low settings saw this jump back up to 110fps. It was a similar story in *Dirt 5* and *Metro Exodus Enhanced*.

The other key component is Intel's Core i9-13900H processor, which features six P-cores that can boost to 5.4GHz. When you need the extra threads, there are eight E-cores. A multicore result of 12,761 in Geekbench 5 reflects this, and is not far behind the 14,070 of the Core 19-13950HX in the Blade 18, or the 15,044 of the M2 Max in the Apple MacBook Pro 16in.

It's also reassuring to see 32GB of DDR5 memory. It ships with a 1TB SSD, but undoing four screws in the base reveals an empty M.2 bay. You can also replace the supplied Gen4 drive, but you can't upgrade or replace the memory, as it's embedded onto the motherboard.

Despite the price, Samsung's Galaxy Book3 Ultra is easy to recommend. It's extremely portable, has a gorgeous screen, great battery life, and the power is there when you need it. –**TIM DANTON**

VERDICT 8

Samsung Galaxy Book3 Ultra

+ BOOK IT Lightweight design; Premium finish; Brilliant screen; Excellent battery life.

– BUCKET Underpowered GPU; Irreplaceable RAM.

$3,000, www.samsung.com

SPECIFICATIONS

CPU	Intel Core 19-13900H (14-core (6 P-cores, 8 E-cores)
GPU	Nvidia GeForce RTX 4070 8GB
RAM	32GB LPDDR5-5200
Display	16-inch non-touch AMOLED 120Hz
Resolution	2,880 x 1,800 resolution
Storage	1TB M.2 PCI-E 4 SSD
Webcam	1080p webcam
Wireless	Wi-Fi 6E, Bluetooth 5.1
Ports	2 x Thunderbolt 4, USB-A 3.2 Gen 2, HDMI 2.0, 3.5mm combo jack, microSD card reader
Battery	74Wh
OS	Windows 11 Home
Dimensions	355 x 250 x 16.5mm (WxDxH)
Weight	1.8kg

© UNSPLASH

Much more portable, but also much more expensive, than a Steam Deck.

OneXPlayer OneXFly

Lighter, smaller, faster, stronger

THE DREAM OF PLAYING PC games in bed has been the long-held desire of the handheld gaming PC crew. But 18 months, regular wrist cramps, and a couple of black eyes later, the general consensus is that the Steam Deck isn't a device you want to be gaming on in bed. Its weight and girth make it an uncomfortable bedfellow, and your companions are unlikely to appreciate it, given the racket the fans make.

But your bedroom will be a happy home for the OneXPlayer OneXFly handheld. It's been designed to be smaller than both the Steam Deck and the ROG Ally, and lighter. It really is a lovely piece of hardware.

While I don't love the OneXConsole application, it's effective enough at giving you easy control over the system. You can also control the RGB, because that's now a thing handheld gaming PCs need. However, I've spent most of my time with the LEDs disabled to squeeze every last drop of power out of the 48Wh battery.

For a handheld, it's all about that longevity away from the plug socket, after all. The OneXFly can comfortably outlast the ROG Ally, even running the awesome Ryzen 7 7840U at the full 30W TDP. With everything at max, including the Windows power settings, the OneXFly delivers 69 minutes of gaming uptime measured by the PCMark 10 gaming battery test.

The AMD Ryzen APU is ludicrously good, while the Radeon 780M RDNA 3 integrated GPU is surprisingly adept at 1080p gaming, generally on medium game settings. The same even rings true when I've been cutting TDP down to 15W to play *Baldur's Gate 3*.

It's an excellent BG3 machine, too. The screen is bright, at 450cd/m2, and it's super sharp, responsive, and clear. The rest of the base spec is pretty standard for the current crop of gaming handhelds—16GB RAM, 512GB SSD—but it's using a speedier version of memory in its LPDDR5X-7500 kit, making it a super-responsive Windows gaming machine.

So the specs are good, the slim bezel screen is neat, and the performance right up there. I'm also liking the physical design—it's thick, but the footprint is far smaller than either Deck or Ally, making it something I'm far more likely to just drop into a bag when I head out.

But it's not cheap, and that's where the Steam Deck still holds sway over any handheld being launched. They may have higher specs, but when you can pick up a low-end Deck and swap in a cheap high-capacity 2230 SSD for around $400, that puts it more in second-machine territory than the $739 price tag of the lowest spec version of the OneXFly.

At that price, it's a primary machine. Can it replace your laptop? If we're just talking gaming, then yes, but you're not going to be able to take notes on your OneXFly in class, or run a PowerPoint presentation without looking silly.

It's a great little device, though. I still love the huge 8-inch screen of the A1 Pro, and its beefy battery, but it's massive. The OneXFly is a genuinely portable, genuinely powerful handheld, with a lot of versatility. I don't love the software, and Windows certainly has its quirks. But I couldn't go back to the Steam Deck or ROG Ally, as they feel too limited for me.

With this in mind, it looks like it'll be the OneXFly that accompanies me on my travels from now on. **–DAVE JAMES**

VERDICT 9

OneXPlayer OneXFly

+ PRETTY FLY That AMD chip is a hero; Screen is bright and crisp; Feels good in the hands; Lots of ports; Quiet.

– NOT QUITE HIP Battery life will always be on your mind; Wobbly top USB4 connection; Expensive; Software is only okay.

$$739-$1,299, onexplayerstore.com

SPECIFICATIONS

Processor	AMD Ryzen 7 7840U
Cores/Threads	8/16
GPU	AMD RDNA 3 12CUs
Memory	16/32/64GB LPDDR5X-7500
Screen	7-inch
Resolution	1920 x 1080
Refresh rate	120Hz (60Hz tested here)
Peak luminance	450cd/m²
Battery	48Wh
I/O	2x USB 4.0 Type-C, 1x USB 3.2 Type-A, 3.5mm audio, MicroSD
Dimensions	264 x 98 x 23mm
Weight	580g

Like many laptops aimed at the gaming crowd, this is a great all-rounder.

Asus Vivobook Pro 16X

A creative laptop with a playful side

THIS VIVOBOOK from Asus is not a gaming laptop. It may look like one, with its GeForce RTX 4070 GPU, 13th-gen Core i9 processor and 3.2K, 120Hz, OLED screen, but there's a subtle difference. The Vivobook is aimed at creative professionals, the sort of people currently glued to Photoshop rather than *Baldur's Gate 3*, and as such comes with Nvidia's Studio drivers installed, rather than the Game Ready ones.

This matters because DirectX 12 needs detailed instructions for the games you want to play. Every time a big title is released, the GPU manufacturers release a new driver to fit it. The same isn't true of the Studio drivers, which are designed to be stable rather than to squeeze every possible frame out of *Armored Core 6*, so while games will run using them, they won't be working at their best.

Thankfully, it's a simple process to install the Game Ready drivers over the top of the Studio ones, although it required us to reinstall GeForce Experience, which added several minutes to the job. Once we were finished, it walked and quacked very much like a gaming laptop indeed.

It even costs about the same as a similarly specced Lenovo Legion Pro 5, though that machine has an IPS screen instead of the glorious OLED that sits atop the Vivobook. We're big fans of OLEDs, though they can be more reflective than we'd like. There's little worse than seeing your own face staring back at you from a low angle while trying to navigate a dark passage in a game (or work on layouts using darker colors in InDesign).

One thing that sets Asus' creative laptops apart is the inclusion of an extra dial at the top of the trackpad. This works with the manufacturer's own software to add custom functions to apps or Windows, such as altering the volume, scrubbing through video timelines, or changing the size of brush tips in painting apps. There's no physical dial on the Vivobook—instead, a corner of the trackpad is fenced off with a circular dotted line. Pull down with one finger from the opposite corner, and an LED illuminates below the circle. You can move your fingertip in this area to emulate the turning of a dial. It's not as satisfying as the real thing, but still useful.

A recent update to Adobe Lightroom and Camera Raw brought neural network-powered noise reduction to the development of raw image files, and your PC's GPU is immensely important in how fast this runs. On a 60MP file, integrated graphics can take several minutes, while the RTX 4070 munches through the task in less than 30 seconds. It's an example of how important fast GPUs like this are becoming for applications outside the realms of games, though it's important to note that the Vivobook is still capable of 60FPS in Horizon Zero Dawn at 1440p ultra settings, too.

This Vivobook, like many laptops aimed at the gaming crowd, is a great all-rounder. It has a sleek, pro look about it, and the battery life is just about acceptable at about five and a half hours in our office work benchmark, but it's the OLED screen that really stands out. It's got a high 3.2K resolution, a fast refresh rate, and the colors and contrast we've come to expect from the technology. There's very little to complain about here apart from the price, and for a laptop packing these kind of specs, that's something we've come to accept. **–IAN EVENDEN**

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VERDICT 8

Asus Vivobook Pro 16X

+ VIVABOOK Great OLED screen; powerful components; Decent cooling.

– NADABOOK Expensive, but not unduly so; A bit heavy; Short battery life.

$2,000, www.asus.com

SPECIFICATIONS

CPU	Intel Core i9-13980HX
GPU	Nvidia GeForce RT 4070 8GB
RAM	32GB
Storage	1TB SSD
Screen	16in OLED, 3200 x 2000px, 120Hz
Connectivity	2x USB 3.2 Gen 1 Type-A, 2x Thunderbolt 4, HDMI 2.1, Ethernet, SD card reader, 3.5mm headset jack, Wi-Fi 6E, Bluetooth 5.3
Dimensions	35.50 x 24.90 x 2.19cm
Weight	1.9kg9

The SN850 is a safe pick-up on the cheap, especially for laptops.

WD Blue SN580

WD Blue Electric Boogaloo

THE WD BLUE SN580 is the consummate budget NVMe SSD, taking a winning formula and making it better. It performs well enough with a fair range of capacities and solid support, making it a contender for our list of best SSDs. It's relatively efficient, and the single-sided design makes it great for laptops. It doesn't bring anything new to the table, but it's an easy pick-up for a budget drive if you're looking for a cheap upgrade that won't disappoint, assuming the price is right.

The success of the Blue SN570 and Black SN770 has prompted WD to revamp the former with the Blue SN580. The SN580 is essentially an updated SN570, much as the SN570 was an updated Blue SN550, which succeeded the Blue SN500. The SN550 was very popular, but WD later changed its flash, negatively affecting performance. That brings us back to the SN580, which jumps up to a PCIe 4.0 interface for more bandwidth, uses a new caching scheme for better burst performance, and generally maintains or improves on the SN570 in every meaningful way.

The warranty remains the same, as does WD's software selection. However, the SN580 is more efficient than the SN570, which is always a welcome development. The drive also borrows from the Black SN850 with a new caching scheme, an improvement for most over the SN570's relatively small cache. Perhaps the biggest ding against the SN580 is that it's otherwise uninspiring; it sets no new records, and isn't even as fast as existing 4.0 drives in its class. It's better than the Black SN750 SE, but that's not saying much. Still, it is a safe buy.

The SN580 is available at 250GB, 500GB, 1TB, and 2TB (we tested the latter). The drive does not support hardware encryption, and is warrantied for five years. The SN580 can achieve up to 4,150/4,150 MB/s for sequential reads and writes, and 600K/750K IOPS for random reads and writes. The former is an improvement over the SN570, but the relatively small amount of gain is from the switch to a 4.0 interface rather than any wild changes under the hood.

WD provides two downloads for its SSDs. The first is the Western Digital SSD Dashboard, or toolbox, which is useful for monitoring the health of the drive, handling firmware updates, and engaging other utilities. The second is a version of Acronis True Image for backing up data.

The SN580 has an SSD controller, one NAND package, and a power management integrated circuit (PMIC). The drive is DRAM-less, but WD has done well without DRAM on the SN570 and SN770 alike. The original SN500 arrived without HMB explicitly enabled, and also performed fairly well. This is possibly due to having more SRAM available for metadata and mapping within the ASIC itself. In any case, HMB is adequate for the intended "light" workloads.

The Blue SN580 is an excellent budget SSD. It's a stretch to call it a PCIe 4.0 drive, but it does bring improved performance and better caching over the SN570 without stepping on the toes of the SN770. In most cases, it will give an equivalent experience to the SN770 at what should be a lower price, although this suggests that the SN770 will eventually be replaced.

The SN580 also has a pretty decent warranty, and the software support isn't bad, either. These aren't major benefits, but when coupled with WD's mature design, it makes for a very reliable drive. It's a good choice regardless of your intended use. WD does have a history of switching up the hardware on its drives, like with the SN550 and the SATA Blue, but as tested and launched, the SN580 is a solid all-around budget drive. It's not the most exciting product we've seen, but that doesn't mean it's not good or that it doesn't have its place. –**SHANE DOWNING**

VERDICT 6

WD Blue SN580

+ VALUE Takes from a winning formula; Easily more efficient than the SN570; Good warranty and software support.

− ADD Last-gen/average performance.

$109.99 (2TB), westerndigital.com

BENCHMARKS

	WD Blue SN850	SK hynix Platinum P41	Samsung 980
PCMark 10 Storage Bandwidth (MB/s)	555	**623**	451
PCMark 10 Latency (µs)	49	**43**	61
PCMark 10 Storage (points)	3,447	**3,897**	2,787
DiskBench 50GB File Folder Copy Transfer Rate (MB/s)	1,501	**1,884**	982
DiskBench 50GB File Folder Write Transfer Rate (MB/s)	**2,160**	1,894	1,654
DiskBench 6.5GB Zip File Read Transfer Rate (MB/s)	2,709	**3,994**	2,304

Best scores are in bold. Our test bench consists of an Intel Core i9 12900K, Asus ROG Maximus Z790 Hero, 2x16GB G.Skill DDR5-5600 CL28, Sabrent Rocket 4 Plus-G 2TB (OS), and Windows 11 Pro.

SPECIFICATIONS

Form Factor	M.2 2280
Interface / Protocol	PCIe 4.0 x4
Controller	SanDisk Proprietary
DRAM	N/A (HMB)
Flash Memory	112-Layer Kioxia TLC (BiCS5)
Sequential Read	4,150 MB/s
Sequential Write	4,150 MB/s
Random Read	600K
Random Write	750K
Security	Pyrite 2.01 (no SED)
Endurance (TBW)	900TBW
Warranty	5-Year

XGIMI HAS CARVED OUT a niche over the last four years on the back of terrific projectors. The Horizon series is the brand's home cinema line, with the standard model offering 1080p resolution and 4K limited to the Horizon Pro. XGIMI is now rolling out a new variant: the Horizon Ultra. Dubbed the next-gen model in the series, the Horizon Ultra features a hybrid LED and laser system, 4K resolution with Dolby Vision integration, and a low-latency gaming mode.

The best part is that the Horizon Ultra isn't selling at a significant premium; the projector is debuting at $1,699—less than what the Horizon Pro launched for two years ago. Looks-wise, this projector is gorgeous; it's not something that you tuck away in a corner. Instead, it's designed to be the focal point of your living room.

XGIMI went with a standard set of ports at the back of the Horizon Ultra: you get dual USB 2.0 ports, two HDMI ports with one designated as eARC, optical and 3.5mm out, and an Ethernet port. When it comes to wireless connectivity, there's Wi-Fi 6 and Bluetooth 5.2 LE. I didn't see any issues with connectivity, and the Horizon Ultra maintained a rock-solid connection to my router over Wi-Fi.

Like most XGIMI projectors, the Horizon Ultra has auto keystone along with auto focus, so setting up the projector is straightforward. XGIMI is rolling out the latest iteration of its Intelligent Screen Adaption tech, which uses a combination of software and hardware to make on-the-fly adjustments to the watching environment to deliver the best picture quality. On the hardware side, the feature relies on sensors that automatically adjust brightness, contrast levels, and colors, and you also get an optical zoom lens that assists with screen scaling.

The Horizon Ultra has a throw ratio of 1.2-1.5:1, and it can project up to a 200-inch image. It is significantly brighter than the Horizon Pro, going up to 2,300 lumens. The Horizon Ultra isn't a native 4K projector, but like other products in this category, it uses pixel shifting to deliver a 4K image with a 1080p source.

XGIMI's Game mode is interesting because it reduces the latency to as low as 18ms, making it the obvious choice if you're interested in gaming on the projector. You don't get 4K at 120Hz, as it's limited to 60Hz, but it still makes a tangible difference over the other modes.

The biggest differentiator for the Horizon Ultra is Dolby Vision integration, and the projector does a brilliant job of handling HDR content. TV shows or movies that are coded with Dolby Vision have excellent color vibrancy and brightness levels, and I didn't see any issues in this area. The projector also handles 1080p and SDR content really well, and overall there's a definite uptick in picture quality over the Horizon Pro.

The Horizon Ultra remote's brushed metal design feels great in the hand. The only quibble I have is no backlit buttons, which is an issue in a dark room.

There's no native Netflix client either. XGIMI has a workaround that makes it relatively easy to install Netflix, but it's not an ideal situation, as you don't get Dolby Vision content—it's limited to 1080p. That said, the fact that you can actually install Netflix and stream content on the service is a big deal in and of itself.

The rest of the software is standard fare; you get the usual Android TV 11 interface, and while I'm not a fan of the recommendations, it is easy to navigate. Even though the projector has just 2GB of RAM, there isn't noticeable lag in daily use, and you get 20GB of usable storage. You also have full access to the Play Store, and can install your favorite streaming services without too much hassle.

Overall, the Horizon Ultra is one of the best 4K home projectors you can get at the moment, and the feature-set, combined with the stellar picture quality, makes the projector an easy recommendation.

–HARISH JONNALAGADDA

VERDICT **9**

XGIMI Horizon Ultra

+ DRIVE-IN Outstanding picture quality; Bright 2,300 lumen projection; Vibrant colors with both SDR and HDR content; Android TV 11 out of the box; Auto keystone correction and auto focus; Dynamically adjusts colors based on viewing surface; Low-latency mode is great for gaming; Gorgeous design.

– DIVE Still no native Netflix integration; No media playback buttons on the projector; Remote doesn't have backlit keys; No 4K at 120Hz.

$1,700, www.xgimi.com

SPECIFICATIONS

Throw ratio	1.2-1.5:1
Image Size	40 - 200 inches
Image Resolution	3840 x 2160
HDR	HDR10 with HLG
Software	Android TV 11.0
Casting	Chromecast built-in, Magicast
Ports	2 x USB 2.0, 2 x HDMI (one with eARC), Ethernet, Optical, 3.5mm out
Connectivity	Wi-Fi 6, Bluetooth 5.2 BLE
Display technique	DLP
Display chip	0.47-inch DMD
Color Gamut	95% DCI-P3
Lamp Life	25,000 Hours
Speaker	2 x 12W Harman/Kardon
Features	Auto keystone correction, auto focus, Intelligent Screen Alignment 3.0, Intelligent Obstacle Avoidance
RAM	2GB
Storage	32GB
Dimensions	224 x 170 x 265mm
Weight	11.5lb (5.2kg)

XGIMI Horizon Ultra

A truly outstanding 4K projector with Dolby Vision

The premium materials make the Ultra look classy and very distinctive.

Asus ROG Strix Scope II 96 Wireless

The best new gaming keyboard in years

BUILDING OFF THE BACK of the excellent ROG Azoth, the new Asus ROG Strix Scope II 96 Wireless is simply the best gaming keyboard I've used in a very, very long time.

I don't say that lightly—I've also been using Corsair's latest creation, the K70 Max, and the Strix Scope II 96 has it beat. Same for the SteelSeries Apex Pro TKL. While both Corsair and SteelSeries boards offer magnetic switches with adjustable actuation, which the Scope II does not, neither matches the sublime typing and gaming experience delivered by the ROG's lubed up switches.

Yes, lubed switches. I'm so glad that this has made the leap from enthusiast boards into more mainstream ones. The process of pulling out every key switch and dropping in some lube in order to make it thwomp good is not something that many PC gamers will have bothered to do, but freshly lubed switches out of the factory mean you don't have to worry about the messy details with the Scope II 96.

A spot of lube makes all the difference. Every key drops lightly into place as you type, and smoothly springs back with a satisfyingly light clack. The ROG NX Snow switches are your pretty standard linear key switch with an actuation force of 45g. There's also the tactile and moderately heavier option called the NX Storm. Both actuate at 1.8mm, which is pretty snappy, though not quite as snappy as those aforementioned boards at their lowest adjustable actuations. Not that I noticed that in-game; the Scope II 96 feels extremely responsive.

The Scope II 96 is a relatively quiet mechanical keyboard. The sound of the linear switches is reduced to a light pitter-patter by the sound dampening foam, sturdy PBT plastic keycaps, and switch pads. Lubed up, sturdy stabilizers also keep the larger keys, namely the spacebar, quiet.

I've been using the Corsair K70 Max alongside the Scope II 96 to compare, and there's really no competition: the Scope II 96 is noticeably quieter. You're able to swap out any of the NX Snow switches on this keyboard for keys of your choosing. However, if you don't replace them with lubed switches, I will personally hunt you down. Don't do the Scope II dirty like that.

The Scope II 96 is nearly a full-size board—it importantly retains a full numpad—though it's been squashed down into a more compact chassis. As a result, the delete key is further away from your pinky than normal. If, like me, you use the delete key often, you will have to reprogram your brain to get into the habit of reaching further up for it.

This keyboard still retains a whole lot of multimedia functionality for its size. There's a simple scroll wheel with a single oversized ROG logo button beside it. Press the button and the scroll wheel changes function: it's a volume adjuster, media controls, lighting control, and able to run a couple of hotkeys you can set in the Armory Crate software.

I'm not a huge fan of Armory Crate, but at least the key parts of the board you might wish to set up via the app are quick to access, including the RGB lighting customizations screen and macro setup. There are some handy battery saver controls in the app to play about with as well. Though the battery is generally very good. I've only plugged it in one time so far, and I've been using it between two PCs at once.

It's been a long time since I've been blown away by a new gaming keyboard—so many seemed like carbon copies of what Corsair did 10 years ago—but the Scope II 96 has done just that. It focuses on nailing the mechanics of a mechanical gaming keyboard, and that appeals to the mech keyboard snob in me.

Importantly, it's a cheaper than the Asus ROG Azoth, despite coming with many more keys. We're still talking about an enthusiast keyboard price tag, but with the Scope II 96, at least you're receiving what is in many ways an enthusiast-grade board in return. –JACOB RIDLEY

VERDICT 9

Asus ROG Strix Scope II 96 Wireless

WELL OILED Excellent switch feel; Sound dampening that really works; Hot-swappable switches; PBT keycaps; Adjustable multimedia control wheel; Compact size.

STICKY MESS Armoury Crate app is messy.

$180, rog.asus.com

SPECIFICATIONS

Size	96% (full numpad)
Connectivity	2.4GHz, Bluetooth, USB Type-C
Keycaps	PBT or ABS (review unit: PBT)
Switches	Asus NX Snow or Storm (review unit: Snow)
Hot-swappable	Yes
Media controls	Yes, multi-function scroll wheel
Lighting	Full RGB per-key
Software	Armory Crate

Razer Cobra Pro

An excellent all-rounder that performs admirably

RAZER'S COBRA PRO is pitched as a jack-of-all-trades mouse, ideal for any hand grip and game type. It comes with a 30,000 DPI Focus Pro optical sensor and Razer's own optical switches under the buttons. There are 10 programmable controls and three ways to connect to your PC (2.4GHz, Bluetooth, USB-C to USB-A cable). At roughly 12cm x 6cm, it's a pretty compact mouse, and that means it's not that well suited to larger hands.

At a wincingly expensive $129.99, it's not exactly cheap either. In fact, that price leaves it just $20 short of Razer's DeathAdder V3 Pro. That puts a lot of pressure on the Cobra Pro to deliver the goods. How does it fare?

COMFORT & PERFORMANCE

The Cobra Pro is light, snappy, and responsive, and looks pretty, to boot. In action, it skims effortlessly over your mouse mat, which combined with the accurate 30,000 DPI sensor and grippy rubberized sides, produces a feeling of absolute control and smoothness. Note that when changing between 2.4GHz and Bluetooth modes, I came across a strange sensitivity issue. Despite the DPI rating staying the same in Razer's Synapse app, things felt much slower in 2.4GHz mode. I had to drop the Bluetooth DPI to 1,000 to get something that felt like 1,500 DPI in 2.4GHz mode.

The optical sensors under the main mouse buttons, meanwhile, produced satisfying and responsive clicks, and I never experienced missed or doubled-up click. The mouse wheel, too, is firm, although you don't get the sideways clicks offered on some other Razer mice.

At 77g, the Cobra Pro is not the lightest mouse, and if you're after something that strips out all unnecessary bulk, you should look elsewhere. But I wouldn't describe it as particularly heavy either. For gaming generalists or those who want a quality all-rounder, the Cobra Pro ticks a lot of boxes.

KILLING ME (BATTERY LIFE) SOFTLY

All of Razer's listed 100+ hour battery figures for the Cobra Pro were obtained with the RGB lighting disabled. With the lights on, you'll get far less juice. My review unit arrived with 72 percent charge, and in 2.4GHz mode with the RGB enabled, it died after 18 hours and 40 minutes. I'd expect around 25 hours going from fully charged. A lot of users will probably buy the Cobra Pro intending to leave its light show intact, but if you do, get ready to reach for the charging cable.

Things took a very different turn when I switched off the RGB and moved over to Bluetooth mode. Case in point: after 34 hours of use, I was only down to 93 percent. In other words, the mouse dropped a mere 7 percent battery after nearly double the number of hours it took for RGB to completely kill it the first time around. Turns out the Cobra Pro has a secret Methuselah DLC, and it's activated by turning off the lights.

It's a shame it has to be this way, though, because the lighting is surprisingly attractive. Since most of the RGB is focused on the underside, the effect is rather subtle. Without it, the mouse looks a little plain.

A JACK OF ALL TRADES

The Cobra Pro is not aimed a specific type of user. It doesn't have the 20-button madness of the Razer Naga, for example, and gamers with very specific requirements might want to shop around, but that lack of specialization only broadens its appeal.

So why should you buy it over the superb DeathAdder V3 Pro? Well, its battery life exceeds that of the DeathAdder, although both are fantastic in this area. It also has DPI buttons up top for easy access, a more compact form factor that's better for smaller hands, and that sweet, sweet RGB lighting.

Even without comparing it to Razer's best, the Cobra Pro is a very impressive mouse. It's expensive, for sure, and you're better off treating the RGB as a decadent delicacy that you break out every now and then. But if gaming performance and exceptional battery life are priorities for you, then the Cobra Pro should be on your shortlist. –ALEX BLAKE

VERDICT 8

Razer Cobra Pro

+ SNAKE CHARMER Excellent sensor; Methuselah-tier battery life; Glides across the mat; Comfortable to hold; Beautiful RGB lighting.

– SNAKE OIL Very pricey; RGB destroys the battery life; Looks a bit bland without RGB on; Not ideal for large hands.

$129.99, razer.com

SPECIFICATIONS

Sensor	Focus Pro 30K optical sensor
Acceleration	70G
Speed	750 IPS
Battery	Up to 170 hours in Bluetooth mode with RGB disabled (advertised). Tested to 19 hours in 2.4GHz mode with RGB enabled
Polling rate	Up to 1,000 Hz
Customizable buttons	Seven on top, two on the left-hand side, one underneath
Weight	77g

Pinocchio's built-in arm grinder restores weapon durability.

ACTION ROLE-PLAYING

Lies of P

Even with strings attached, Lies of P holds its own

THERE WAS A MOMENT, after watching Pinocchio carve through his 200th rampant puppet with a squeal of grinding gears, when I wondered how we got here. Impossibly, in a year where *Elden Ring*'s expansion is still waiting in the wings and *Lords of the Fallen* is reusing the name of 2014's most middling Soulslike, our best shot at an off-brand *Dark Souls* is a Korean-Italian puppet and his chatterbox cricket companion.

But somehow you can put an oversized bonesaw in Pinocchio's hands and it just feels right. While *Lies of P* trips over some mechanical clumsiness and can't escape its inspirations, it's a competent action game with a unique toolset for experimentation. Maybe more impressively, through the grim spectacle of puppet violence, it's a successful gothic folktale reimagining.

Pinocchio is cool now. That simple assertion is the source of a lot of *Lies of P*'s joy: Instead of the jolly singing puppet, he's a blank-faced metal death machine with a strong Timothee Chalamet aura. He's the kind of weaponized pretty boy you need when "Ergo", the miraculous, mysterious fuel powering your city's puppet automata workforce, turns them into a legion of homicidal robots. It's such an absurd fiction that even in spots where the gameplay falters, knowing I was fighting as Pinocchio without the whole thing feeling ridiculous was a source of almost manic, surreal glee.

Pinocchio's main combat options are built from standard Soulslike pieces: I've got a dodge, light, and heavy attacks—no shields, but I can block with any weapon. There's some *Sekiro* in here, too. Perfect Guards nullify damage if I block during a tight parry window, and building up Stagger damage on enemies opens them to execution attacks. And of course, *Bloodborne*'s DNA filters through, with the chance to attack and regain health lost from blocked chip damage. *Lies of P* pairs the familiar with audiovisual heft: Pinocchio's gears grind as he attacks and his hits land with sprays of sparks, giving a satisfying impact to the piston-driven steel behind his weapon swings.

Unfortunately, *Lies of P* doesn't always benefit by inviting the comparison. Pinocchio doesn't transition between actions as smoothly as the muscle memory I'd built up from *Dark Souls* would expect, which cost me a few victories.

Ergo serves as the souls equivalent. The similarities continue, straight through the interface design and Krat's distinctly Yharnam vibe. I won't lie: the borrowing from its *Souls* forebears is stark. At one point, while descending into some spooky woods after a boss fight in a church against a giant mutated priest, I couldn't shake the awareness of how closely it matched the sequence of beats I'd played in *Bloodborne*.

Even one of Pinocchio's defining abilities, his Legion Arm, feels like a FromSoft appropriation. It's a metal limb that I can swap out at bonfires—sorry, "Stargazers"—to equip different combat gadgets. It's like having a Swiss Army Knife for an arm, if a Swiss army knife had a flamethrower, an acid launcher, and an arm cannon that shoots a delayed charge that embeds into enemies.

By the end of my playthrough, my weapon of choice paired the nimble attack animations of a curved greatsword handle with the reach, damage, and defensive bulk of a bonesaw blade. The lack of multiplayer means I couldn't measure my cleaver against the rest of the world's weapons in Pinocchio combat, though, which feels like missed puppetential.

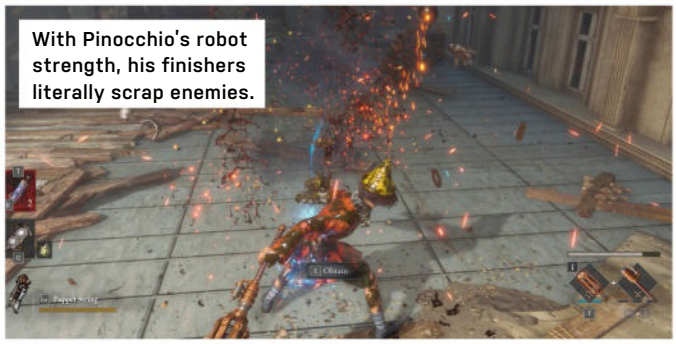
Unfortunately, a mishap with my P-Organ made the first half of my playtime miserable. Every fight felt stiff,

© NEOWIZ GAMES

Puppets aren't the most horrifying things that Pinocchio fights...

Sophia, aka the Blue Fairy, aka level-up lady.

...but the puppet babies come close.


With Pinocchio's robot strength, his finishers literally scrap enemies.

and I never got more comfortable with the combat. Turns out it's because I skipped over an early P-Organ upgrade to Pinocchio's dodge that so dramatically changed how responsive the game felt, I'm baffled that it's optional in the first place. *Lies of P* is so much better in the hands when you aren't playing it with the equivalent of Goku's weighted training clothes slowing you down.

There's a mismatch between parts of *Lies of P*'s combat logic, too. Legion Arms and my weapon's Fable Arts are meant to be core elements of my personal combat philosophy, but stingy resource management keeps me from reaching for them. When boss fights already expect me to juggle my health, stamina, and weapon durability, I'm not going to fumble for consumables to top up my Legion and Fable meters when I can just go with a good old weapon swing.

Some choice boss fights offer that good Soulslike feeling of learning the choreography to a dance; others felt like rolling the dice, hoping I'd luck into a string of attack patterns, especially when the game started dipping into bosses with multiple health bars. Complicating this further, aside from brief side paths for hidden items and opening doors for shortening your corpse runs, *Lies of P* is a linear game. If I was stuck bashing my head against a multi-phase boss, I couldn't bounce over to optional zones or alternate routes for a change of pace.

Still, after realizing that I could be dodging attacks more than a third of the time, I had some thrilling moments marching Pinocchio into battle with my custom-built puppet cleaver. Even when I was stuck on a one-way road in puppet purgatory, the scenery softened the blow. *Lies of P* has some truly gorgeous environmental art, benefiting from attention to architectural detail and lush lighting tech. Some of *Lies of P*'s best moments came when I turned a corner and was met with a lovingly composed line of sight across the fog-blanketed ruin of Krat, puppet corpses impaled on the spokes of the entertainment district's ferris wheel as a warning from the city's survivors.

And the fits? The fits are excellent. I've picked up a whole wardrobe of costumes, from *Bloodborne*-ass dusters to fancy-lad frills, which I can pair with filigreed animal masks and wearable donkey heads. Pinocchio can chart some bold courses for fashion, whether I'm in the mood for a look that says "lethal street-stalker" or "unhinged robot urchin."

As far as the lies go, they aren't very exciting, despite dialogue choices being a novel addition to this type of game (and how big a deal *Lies of P* makes of Pinocchio being the only puppet who can tell untruths). They act as moments where I had to choose between lying to be kind, becoming more human in the process, or just being a little asshole. But those dull lies have an interesting outcome, with implications for the story that I enjoyed puzzling out.

Somehow, *Lies of P* pulls off its gritty Pinocchio retelling, managing the impossibility of incorporating elements from both the folktale and the 1940 movie without feeling, you know, absurd. Even when moments of spotty localization threatened the vibe, *Lies of P* can achieve an arrestingly creepy tone (though it's still only the second-darkest version of *Pinocchio* released in the last 12 months).

I didn't start the year expecting to be compelled by the connections between Pinocchio's origins, the puppet frenzy, a cursed miracle fuel, and wishing on stars, but here we are. Crickets lead you to strange places. –LINCOLN CARPENTER

VERDICT 7

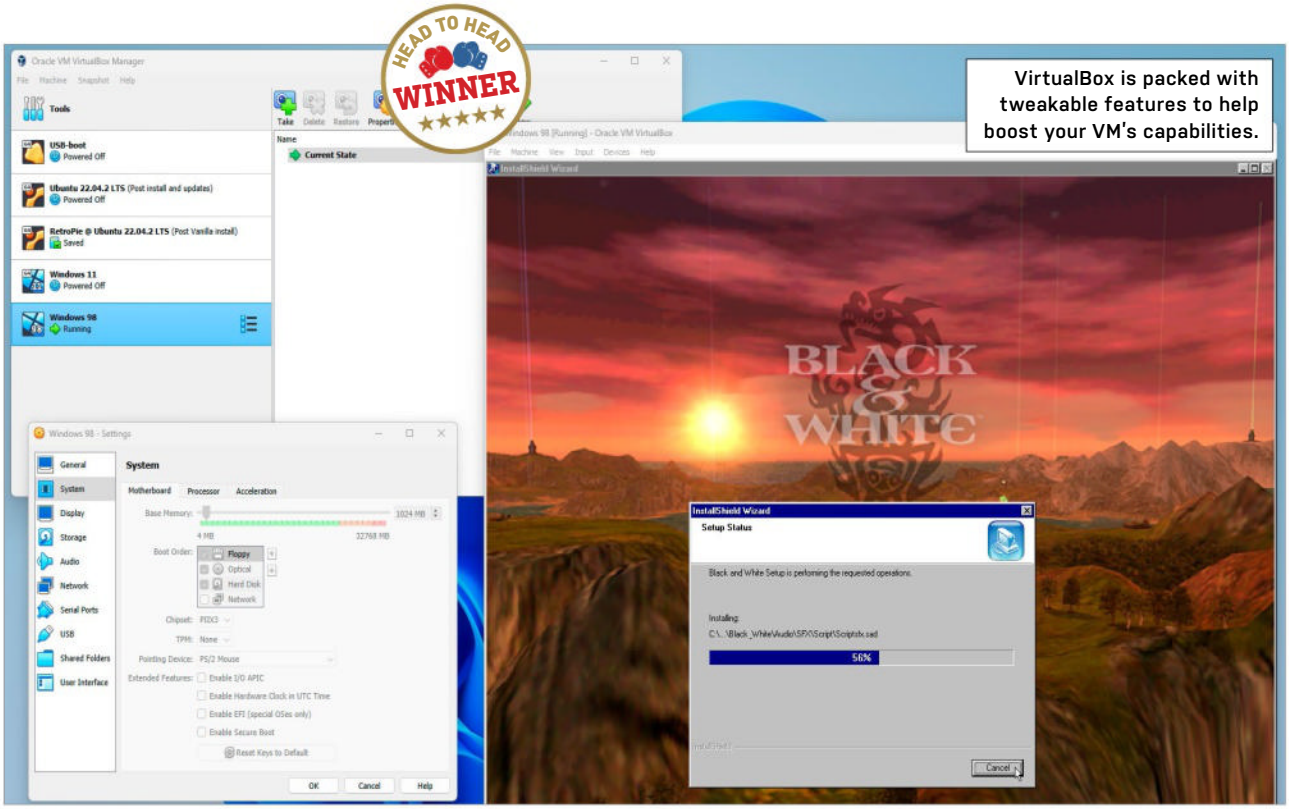
Lies of P

+ PUPPET MASTER: Weapon assembly helps tailor your playstyle; Narrative elements are thoughtful and confluent; Innovates the genre while still feeling familiar.

– WOODEN Execution of stagger mechanics feels dubious; Asset repetition can spoil immersion.

RECOMMENDED SPECS CPU: AMD Ryzen 3 1200 / Intel Core i3-6300, GPU: AMD Radeon RX 6500 XT 4GB / NVIDIA GeForce GTX 1660 6GB, RAM: 16GB.

$59.99, www.liesofp.com, M-rated



VirtualBox is packed with tweakable features to help boost your VM's capabilities.

VirtualBox vs VMware Workstation Player

What's best for running virtual machines for free?

WHETHER YOU'RE LOOKING to recreate an older version of Windows to play classic games or try different flavors of Linux without having to set up a dual-boot system, virtualization is the answer to your prayers. The good news is that it costs nothing to emulate OSes on your PC thanks to these two options, both of which are free for personal use. But which one is better? We put both to the test to find out.

Superficially, both VirtualBox and VMware Workstation Player do the same thing, but there's plenty of differences to mark them distinct from each other. If we start with VirtualBox, it's free to use, and mostly open-source, so there are no restrictions in play unless you need access to fast USB peripherals, in which case a non-commercial restriction applies. In contrast, the free version of VMware is restricted to personal use only, while it also strips out some key functionality for those who don't want to pay for a commercial license. More on those shortly.

Both VirtualBox and VMware can emulate a wide range of Windows and Linux OSes—32-bit as well as 64-bit. They can both technically run macOS in certain circumstances too, but it's completely unsupported, and the steps can be tortuous to follow.

Installation of both tools is straightforward, although VMware does ask some slightly opaque questions during installation—what, for example, is the benefit of the Enhanced Keyboard Driver (that forces a system reboot if installed)? Answer: none, in most cases.

Your emulated machines store their data in special files that mimic virtual hard drives—VMware is exclusively tied to its own VMDK format, while VirtualBox can work with VMDK and VHD (Microsoft) formats, as well as its own native VDI format. This means you can technically attach VirtualBox to hard drives created in VMware, making switching simple.

Installing your virtual OS is a similar procedure : create a VM (virtual machine), attach your chosen OS install media, then tweak various hardware settings to improve performance without taking too much away from your underlying PC. The VM then runs in its own window, inside which you install your chosen OS as if you were installing it on a separate PC.

Both VMware and VirtualBox attempt to simplify this process with an 'Easy Install' (VMware) or 'unattended installation' (VirtualBox) feature on supported OSes. In theory, you simply supply additional information, such as your choice of username and password, that the VM tool then inserts during the install process.

It's not foolproof—you're limited to local user accounts in Windows, while both tools proved problematic with Ubuntu. VMware's Easy Install failed to do anything, while VirtualBox's solution fails to add your user account to the all-important sudo users group, which forces you to apply a fiddly fix.

Once installation is complete, you'll find yourself at your chosen desktop with

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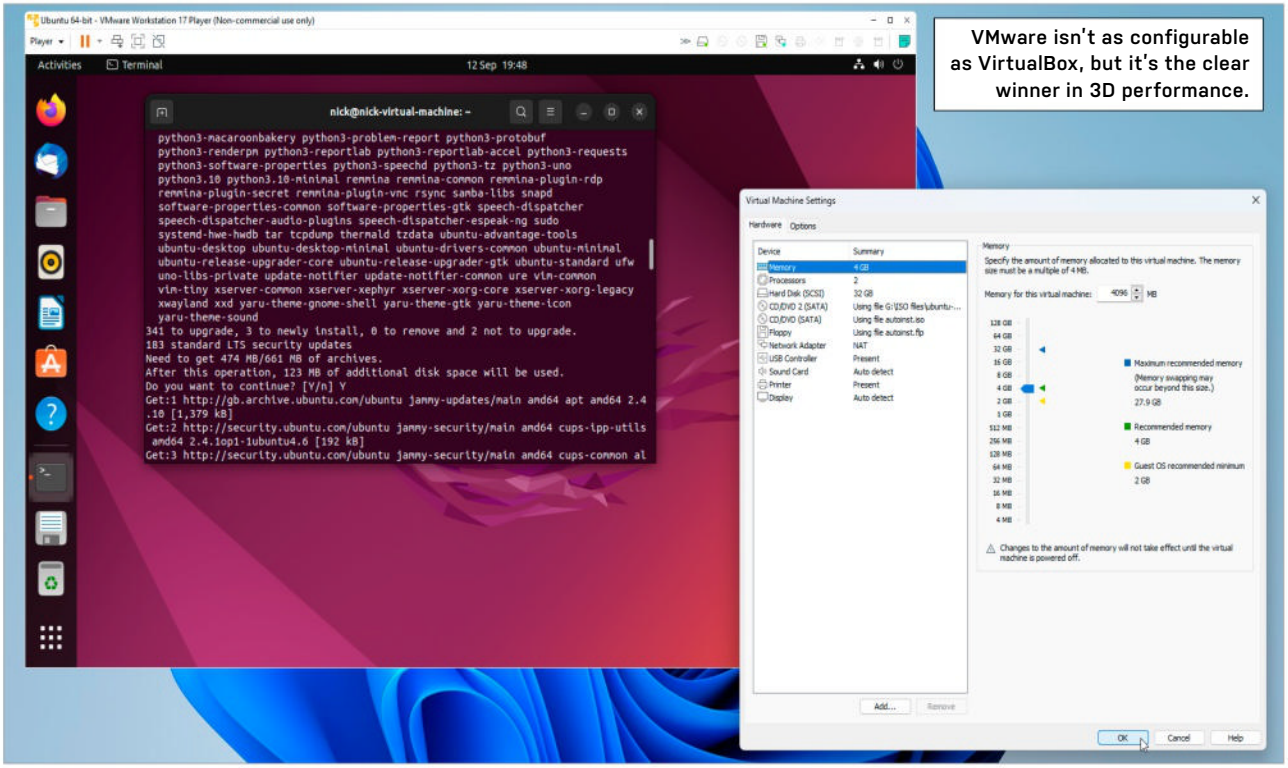

VMware isn't as configurable as VirtualBox, but it's the clear winner in 3D performance.

all basic drivers installed. As things stand, however, you need additional drivers and tools to unlock the full potential of your VM—support for 3D graphics and a full range of desktop resolutions, for example, or the ability to share keyboard, mouse, and data between VM and host with ease. Neither tool offers this as part of their easy install routine, but they're equally accessible (choose 'Player > Manage > Install VMware Tools' or 'Devices > Insert Guest Additions CD Image' respectively).

COMPARING PERFORMANCE

In everyday use, both products offer similar performance. Obviously, your host's underlying hardware, from your processor and RAM to hard drive type and speed, all play a key role—and if you have the processor cores and RAM to spare, you'll want to allocate as much as possible to make a noticeable difference to the speed of your VMs; nevertheless, they'll (understandably) always lag behind the equivalently specc'd native hardware.

Benchmarks reveal that VMware has a small edge over VirtualBox in processor and RAM scores on comparable setups, but it does offer improvements when it comes to graphics performance, particularly in 3D. This is down to several factors: first, VMware can allocate more RAM to your virtual GPU—up to 8GB versus VirtualBox's paltry 256MB (which reduces to 128MB when 3D acceleration isn't enabled). VMware also supports newer technologies—DirectX 11 and OpenGL 3.3 versus VirtualBox's somewhat creaking Direct3D 9 and OpenGL 3.0—which also opens access to a wider range of games.

It's fair to say you wouldn't be running the latest cutting-edge games in either virtual machine, but if you're looking for some nostalgic gameplay with 3D-heavy titles that don't run in Windows 11, VMware is likely to deliver better results.

In non-gaming use, however, there's less to call between them, although VMware does at least boast native support for USB 3.1 (VirtualBox's free extension pack limits you to USB 3.0). Elsewhere, however, you're likely to find VirtualBox's flexibility and lack of restrictions make it the more compelling choice.

For example, VirtualBox allows you to create multiple snapshots of your machine, so you can roll back the changes and use your VM as a test bed; snapshots aren't supported in the free version of VMware, which is especially disappointing when you discover them in the free version of VMware Fusion, the macOS equivalent. VirtualBox is also more configurable, with a wider range of choices when configuring VMs—including hardware tweaks that can claw back some of the performance deficit—compared to VMware.

Ultimately though, your choice will be driven by your needs—if it's gaming (and 3D gaming, at that), then it doesn't matter how limited VMware is; its performance edge means it'll win the day. For all other needs, however, you're likely to err towards VirtualBox's greater set of features, open-source ethos, and lack of restrictions. But since you can install both side-by-side, why not enjoy the best of all worlds and use both? –NICK PEERS

VERDICT 9 KICK ASS!

VirtualBox

VIRTUAL HEAVEN Varied and powerful set of features; Lots of tweaking options.

VIRTUAL HELL Weak 3D (and therefore modern gaming) performance; Only supports USB 3.0 speedsx.

RECOMMENDED SPECS 64-bit Multi-core CPU, 8GB RAM, fast drive to store VMs on.

Free and open source

VERDICT 8

VMware Workstation Player

BLUE PILL Superior performance on DirectX 11-compatible games; Pop-up hints and tips.

RED PILL Key features missing from the free version; Less configurable than VirtualBox.

RECOMMENDED SPECS 64-bit Multi-core CPU, 8GB RAM, fast drive to store VMs on.

Free version feature-limited, www.vmware.com, commercial license from $149

© VMWARE

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Mobo Connector Hate
> Back Issue Issues
> Digital Reader Help
> Firefox Returns

Consistency Qualms

In his September 2023 Build, Sam mentioned his frustration with connectors. I thought I would share my least favorite, in addition to the case front, which he also lamented over.

First is the USB 3.1 connector, which is often nigh-on impossible to plug into the motherboard. Next comes the 3-pin 5-volt RGB connector. The pins are incredibly fragile, the connector rarely stays put on the motherboard, and more often than not I fall at the first hurdle, as I can't even get the connector onto the pins.

It would be so lovely if manufacturers could help solve this problem and develop connections that are sturdy, easy to use, and unmistakable.

On the subject of RGB, I've been exceedingly frustrated with many RGB fans. The problem is that manufacturers who make wonderful unlit fans can't seem to manage putting a few lights on those fans and make them work as efficiently. They're either too loud, don't have adequate airflow, or both.

However, I finally found a worthy RGB fan—the Asus TUF Gaming TF120 has decent RGB, great airflow, and is reasonably quiet. I just installed them in my case—I didn't use the included controller; I just hooked them into my RGB system, and I'm controlling them in iCUE. I've decided that it works better than SignalRGB, and with the new Murals feature in version 5, you can take any MP4 and turn it into a mural. Pretty snazzy!

My final nitpick—don't you think it a bit ironic that after your explanation for why you only provide technical information for Windows 11, you specify Windows 10 in your Blueprints section?

I LOATHE inconsistency!

–R. Matlow

Asus's TUF RGB fans, as recommended by reader R. Matlow.

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thank you for your thoughtful comments on everything from motherboard connections to magazine inconsistencies! Let me answer your points one-by-one.

Yes, connecting up fiddly case and fan cables to easily damaged motherboard pins has to be one of my least-favorite steps during any build, so kudos to Sam and what must be very dextrous fingers for doing it month in, month out! With so many other components and cables packed into such a small space, even the most organized builder will have to go back and do things again after connecting up the wrong cable to the wrong header, or allowing something to come loose when putting things back together.

Of course, your suggestion for better connectors is a good one, but with so many motherboard manufacturers and case/fan makers, that's not an easy thing to do. I'm sure there's a solution, and the motivation would be that building a PC would become a little less intimidating for those giving it their first go.

Thank you for your suggestion on the Asus TUF Gaming fans—the TUF line is the Taiwanese manufacturer's more budget line, so I'm glad you've found good

↘ submit your questions to: editor@maximumpc.com

performance and value for money there. It reminds me that we're long overdue a case fan feature or roundup, as we've become a bit dependant on cases from NZXT and fans from Corsair in the last year.

And yes, you're right to point out that we're still listing Windows 10 in our Blueprints section, but we also make it clear that you can upgrade to Windows 11 for free! While Microsoft continues to offer a free upgrade, we'll continue to list this way, so it's clear to other readers that you still have a choice on what OS to use. Personally, I'd make the leap to the newer version, but I'm using my PC primarily for gaming and personal work—if I was doing anything critical I might fall back to the stability of Windows 10.

Back to the Future

In the May 2023 issue, you mentioned creating a digital archive of back issues, but you did not say how to access the archive. I had switched to a digital subscription just a few months before *Maximum PC* announced going all digital, but I subscribed through Zinio. Is the archive only available to those managing their subscription through www.magazinesdirect.com, like I did with the print version? Always being behind on my reading, I missed the July and August issues before I realized my subscription had ended.

–R. Fuller

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thanks for your question, and sorry to hear you've been having issues with accessing our back catalog. Yes, I should have been clearer—our digital archive is for those who subscribe through our publisher Future's online subscription service Magazines Direct (see page 40 for details). The magazine is sold in single issue and subscription form through third parties like Zinio, but as these stores aren't owned by our publisher, we're unable to control their offering. Hopefully that makes sense, and makes things clearer for anyone else who was unsure about this.

As I look on the site, at the time of writing we're doing a one-year subscription (13 issues) for $20 and two years (26 issues) for $30, which includes access to over 100 back issues as part of the subscription. I think that's pretty good value!

Digital Issues

I haven't been able to read an issue of *Maximum PC* since you went digital. I have contacted Pocketmags a few times, but they have been no help. I wonder how many others have not been able to access their magazine subscription.

I see my subscription, which was a gift, but when I click on any link to go to an article, I am presented with a bad URL, such as https://page//28.

Please assist me in getting this working. I am using Windows 11 on my PC that I built using your magazine. I am using Google Chrome.

Thanks for your time and support. **–D. Milligan**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thanks for contacting me about this issue. It's not something that anyone else has written to me to ask about, I have to say. It's great to hear that you built a machine following one of the guides in the magazine though—please follow up and let me know which one you went for.

I went into my own Pocketmags account, also through a Chrome browser and on Windows 11. I clicked through a number of different magazines and issues that I had in my account, and everything was working fine. It appeared to be using HTML5 in order to display the pages, and all of the Pocketmags' functionality, including links and printing, seemed to be working fine.

I'll follow up with Pocketmags to see if that helps, but I would also suggest using a different browser (perhaps Opera, a guide to which we feature this issue on page 32), or on a different device, such as a mobile or tablet. It's frustrating, I know, but I wouldn't want you to miss out on any *Maximum PC*!

What Does the Fox Say?

I've been a reader of *Maximum PC* since the 00s. I love you guys, and I love getting caught up with the PC industry!

One thing I have noticed recently is that I haven't seen you mention Firefox at all. I've read a few articles regarding browsers, privacy, etc, including the most recent article in your Sep 2023 issue, and Firefox isn't a contender. I'm wondering why? I've been using Firefox for around 20 years, but I'm wondering if maybe it's time for me to look into other options. I'm curious to check out the DuckDuckGo browser, but I'm so entrenched with Firefox that I hesitate. I know it's a resource hog, which gets under my skin, but it hasn't been enough for me to want to switch. I would love to hear your feedback about why Firefox hasn't been in the *Maximum PC* lexicon recently, and maybe some arguments as to why I should look into other options.

I greatly value *Maximum PC*'s insight and wisdom. The times may change, but *Maximum PC* remains the same: awesome!

PS: Please also bring back the iFixit teardown articles! **–A. Sorich**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thanks so much for your email—it's always nice to hear from a longtime reader who thinks we're doing a good job. You raise an issue that has been on my mind recently, which is that we've tended to default to Google Chrome when referring to web browsers or doing a guide on them. That's why we have a tutorial on tab islands in Opera on page 72 of this issue.

However, Opera is still a Chromium-based browser (which, like Microsoft Edge and Brave, are based on the same underlying engine), which has its benefits, such as being able to use things like plug-ins across a variety of browsers and devices, but ultimately there are better browsers out there when it comes to things like privacy.

This brings us to DuckDuckGo and Firefox, which you mentioned in your letter, both of which focus on privacy in terms of their USP. I personally keep meaning to give DuckDuckGo a try, as like most other people, I am wary about how much of my personal information is tracked as I browse, and find the constant follow-up ads annoying because of the cookies I've dropped on my travels. I used to use Firefox before I moved to Google Chrome in the late 2000s, and am always tempted to go back, so will keep this in mind for future tutorials, or maybe even a feature on the best browsers in 2023.

I noticed that one of my favorite extensions, Pocket (which allows you to save articles to read later), is now owned by Firefox's parent company Mozilla. This also reminded me to give it a go, as well as the email client Thunderbird, which is also owned by the company, and we've been mentioning quite a bit in recent issues.

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THE BUILDS

THIS MONTH'S STREET PRICES...

THE GPU MARKET is hard to keep up with these days, especially in terms of pricing. But the upside is that there are now some very interesting, if often fleeting, deals to be had. That's a welcome change from 18 months to two years of hideously high pricing during the pandemic.

Anyway, here's one we'd like to swing past you. How about an AMD Radeon 6700 XT 12GB for $320, including a copy of *Starfield*? If you were going to buy *Starfield* anyway, take $70 off, making the effective price $250.

Into our AMD rig it goes. Sure, it's last-gen versus the Radeon RX 7600 it replaces, but critically, it has 12GB, where the 7600 has just 8GB. 8GB is becoming an increasing limitation, even at 1080p. Moreover, the new RX 7000 range brings very little in terms of new technologies. Dollar-for-dollar, it's not any better at ray tracing than the old RX 6000 family, so it's really just a question of raw performance, and the 6700 XT is a solid 30 percent faster. But it's not nearly 30 percent more expensive.

You can't make quite the same argument with Nvidia GPUs, because the latest RTX 40 cards have significant technical upgrades. So while it's tempting to drop in a 3060 Ti from the last gen for its marginally superior raster performance to the 4060, there's a lack of support for Frame Generation.

We're going to take a similar approach with CPUs and slap in a last-gen Intel Core i5 12400F. It's notable that 12th Gen and 13th Gen Intel CPUs are exactly the same architecture on exactly the same process node, it's just the 12400F has six Performance cores to the 13100F's four Performance cores—50 percent more cores for 35 percent more money. We can compensate for that with a slightly cheaper RTX 4060 board in the ZOTAC GAMING GeForce RTX 4060 8GB Solo, ensuring that our six-core rig only costs $20 more than last month's quad-core machine.

AMD INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	600W EVGA 600 GD 80+ Gold	$70
Mobo	MSI B550M PRO-VDH WIFI Micro ATX AM4 Motherboard	$105
CPU	AMD Ryzen 5 5600	$138
GPU	PowerColor Fighter AMD Radeon RX 6700 XT 12GB NEW	$320
RAM	16GB (2 x 8GB) PNY XLR8 Gaming EPIC-X RGB DDR4 @ 3600MHz	$45
SSD	1TB Lexar NM790 PCIe 4.0 M.2 SSD	$70
HDD	2TB Seagate Barracuda Compute 7200	$50
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$925**

INTEL INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	600W EVGA 600 GD 80+ Gold	$70
Mobo	ASRock B660M Pro RS Micro ATX GA1700	$95
CPU	Intel Core i5-12400F NEW	$150
GPU	ZOTAC GAMING GeForce RTX 4060 8GB Solo NEW	$279
RAM	16GB (2 x 8GB) PNY XLR8 Gaming EPIC-X RGB DDR4 @ 3600MHz	$45
SSD	1TB Lexar NM790 PCIe 4.0 M.2 SSD	$70
HDD	2TB Seagate Barracuda Compute 7200	$50
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$886**

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TAKE IT FROM A GEEK.℠

WHEN IT COMES TO GAMING, these mid-range machines are all about high-refresh 1440p with a side order of 4K at more modest frame rates. Happily, achieving that has just got a fair bit cheaper.

The main reason is the arrival of the AMD Radeon RX 7800 XT at $500. Okay, it only represents a very small step in performance over the old 6800 XT, which can now be had for similar money, but that GPU is not long for this world. More to the point, as a new-gen GPU, the 7800 XT puts much more pressure on Nvidia than the last dregs of an older generation being sold off cheap.

That's why several lower end and mid-range Nvidia RTX 40 Series graphics cards have had haircuts. You can now get an RTX 4070 for $550. That's still not a bargain, especially given the AMD 7800 XT is cheaper, but faster for raster, if not for ray tracing, and has more VRAM. But the RTX 4070 is now down to a level where we'd be reluctant to opt for the particularly poor RTX 4060 Ti.

So in goes the ASRock Challenger Radeon RX 7800 XT 16GB to our mid-range AMD build. At $500 it's more expensive than the 6800 vanilla card it replaces, but as a new-generation GPU, it's a much better long-term bet. Elsewhere, we're sticking with the six-core Ryzen 5 7600X, which remains an excellent gaming CPU, as well as all the other key components, including the Asrock B650 motherboard, 32GB of Corsair DDR5, and a 1TB Lexar SSD. The total price for the rig edges up to $1,500 on the nose.

As for the Intel rig, we're all too happy to ditch the MSI VENTUS 2X BLACK OC GeForce RTX 4060 Ti 8GB in favor of an MSI Ventus GeForce RTX 4070 12GB. While it's a fairly substantial step up from $390 to $550, we reckon it's worth every penny. The 4060 Ti ultimately isn't well equipped for 1440p gaming. It's not even great shakes at 1080 in some games that eat up a lot of VRAM, so we'd far rather pay $1,607 for a proper 1440p rig than $1,447 for something sub-standard.

AMD INGREDIENTS

PART		PRICE
Case	NZXT H7 Flow	$130
PSU	750W EVGA 750 BP 80+ Bronze	$90
Mobo	ASRock B650M PG RIPTIDE Wi-Fi Micro ATX AM5	$200
CPU	AMD Ryzen 5 7600X	$240
Cooler	MSI MAG CORELIQUID 240R V2	$90
GPU	ASRock Challenger Radeon RX 7800 XT 16GB NEW	$500
RAM	32GB (2x 16GB) Corsair Vengeance DDR5 CL40 @ 4800MHz	$98
SSD	1TB Lexar NM790 PCIe 4.0 M.2 SSD	$70
HDD	2TB Seagate Barracuda Compute 7200	$50
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$1,500**

INTEL INGREDIENTS

PART		PRICE
Case	NZXT H7 Flow	$130
PSU	750W EVGA 750 BP 80+ Bronze	$90
Mobo	Gigabyte Z790 UD AC ATX LGA 1700	$180
CPU	Intel Core i5-13600K	$317
Cooler	MSI MAG CORELIQUID 240R V2	$90
GPU	MSI Ventus GeForce RTX 4070 12GB NEW	$550
RAM	32GB (2x 16GB) Corsair Vengeance DDR5 CL40 @ 4800MHz	$98
SSD	1TB Lexar NM790 PCIe 4.0 M.2 SSD	$70
HDD	2TB Seagate Barracuda Compute 7200	$50
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$1,607**

AS EVER WITH OUR FASTEST BUILDS, the opportunity for radical change is somewhat limited. Once you already have the fastest available AMD or Nvidia GPU, you can't really upgrade it, at least not until those rare occasions when a new generation of graphics hardware is released. Likewise, CPUs—new chips only come along so often.

That said, it's worth noting that AMD is making a bit of a push with *Starfield* bundles of late, so you can effectively subtract $70 from most Radeon RX 7000 series board prices. This month, we'll go with the PowerColor Hellhound Radeon RX 7900 XTX 24 GB, which is yours for $940 from Amazon, and effectively $870 with *Starfield* thrown in. That's a decent discount on the $999 launch price of the 7900 XTX, and a good deal for a GPU, with raster performance comparable with an RTX 4080 which costs around $200 more.

That said, it's nice to note that the ASRock X670E PG Lightning ATX AM5 has dropped by $30 this month, reducing the overall AMD rig price down below $2,900. Pretty impressive for a machine with everything just about maxed out.

Over on the Intel side of the divide, Nvidia's RTX 4090 remains stubbornly stuck at $1,599. Still, that is actually a relatively decent deal for what is absolutely, unambiguously the fastest GPU you can buy, and will remain so for at least another year, and quite possibly well into 2025, what with Nvidia's next-gen RTX 50 series looking like it won't arrive until early 2025, and AMD rumored to have cancelled its high-end RDNA 4 GPUs.

That said, there are very slim savings to be had by swapping out the Intel Core i9-13900K for the 13900KF alternative. The two chips are identical, save for the integrated graphics being disabled in the "KF" model. You're not going to be using that silly integrated graphics in the "K" model, are you? So there you go, we're swapping it in. We've just saved you $11, bringing the overall price down to $3,420. To quote the long-suffering Dr Lazarus, by Grabthar's Hammer, what a savings.

AMD INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$190
PSU	1000W NZXT C1000 80+ Gold	$180
Mobo	ASRock X670E PG Lightning ATX AM5	$230
CPU	AMD Ryzen 9 7950X3D	$660
Cooler	NZXT Kraken X73 RGB 360mm	$300
GPU	PowerColor Hellhound Radeon RX 7900 XTX 24 GB NEW	$940
RAM	64GB (2x 32GB) Corsair Vengeance DDR5 CL40 @ 5200MHz	$165
SSD	2TB WD Black SN850X M.2 PCIe 4.0	$99
HDD	6TB WD Blue 5400 HDD	$100
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$2,896**

INTEL INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$190
PSU	1000W Corsair RM1000x Shift 80+ Gold	$210
Mobo	Gigabyte Z790 UD AC ATX LGA 1700	$180
CPU	Intel Core i9-13900KF NEW	$545
Cooler	NZXT Kraken X73 RGB 360mm	$300
GPU	Zotac GeForce RTX 4090 GAMING Trinity OC 24GB	$1,599
RAM	64GB (2x 32GB) Corsair Vengeance DDR5 CL40 @ 5200MHz	$165
SSD	2TB WD Black SN850X M.2 PCIe 4.0	$99
HDD	6TB WD Blue 5400 HDD	$100
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$3,420**

Maximum PC (ISSN 1522-4279) is published 13 times a year, monthly plus a Holiday issue following the December issue, by Future US LLC, 130 West 42nd Street, 7th Floor, New York, NY 10036. USA. Website: www.futureus.com. Future US LLC also publishes *MacLife*, and *PC Gamer*. Entire contents copyright 2023, Future US LLC. All rights reserved. Reproduction in whole or in part is prohibited. Future US LLC. is not affiliated with the companies or products covered in *Maximum PC*. Reproduction on the Internet of the articles and pictures in this magazine is illegal without the prior written consent of *Maximum PC*. Products named in the pages of *Maximum PC* are trademarks of their respective companies.

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